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A Regime Shift Analysis of Poverty Traps in sub-Saharan Africa:

Identifying Key Feedbacks and Leverage Points for Change

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INSTITUTIONEN FÖR GEOVETENSKAPER

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PREFACE

Having been born and grown up in one of sub-Saharan Africa (SSA) poorest countries, I have experienced failures of many development programmes intended to improve lives of millions of rural communities in my home country, the Democratic Republic of the Congo (DRC). Later when I completed my university studies in agriculture sciences, I took part in some of these programmes. Unfortunately, I have come to realise that the situation of most SSA rural communities, including the ones in my own country, far from getting better are getting worse. The response has been to improve the understanding of what poverty is so that appropriate interventions can be implemented in order to combat poverty. Thus, many innovations to deal with poverty have been suggested and policy initiatives have been accordingly developed and implemented, but only to realise that the welfare of people and communities is not improving much. The question is what is not working? Has the assessment of poverty something to do with what appears to be a lack of effective intervention schemes? As for me, I think it has. Although participatory poverty assessments have claimed to be the means by which economic understanding of poverty can be approached, I think the regime shift framework has much to offer in that it allows a hard look at the core social and natural interactions or processes that generate poverty traps. In so doing, alternative courses of action could be highlighted for both informed management interventions and ensuring sustainable livelihood of rural places.

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Johnny Musumbu Tshimpanga

ABSTRACT

Smallholder livestock keeping and agriculture systems in the sub-Saharan Africa (SSA) seem to be caught into poverty traps, in as much as they cannot any longer provide ecosystem services on which local communities depend for their survival.

I used a regime shifts framework to carry out a thorough assessment of these two case studies in arid and semi-arid lands and smallholder by identifying relevant traps and alternate desirable regimes. Using systems analysis and modelling, I drew casual loop diagrams of the two case studies, which helped me to identify the feedback loops that maintain the systems in undesirable traps and the external driving forces of change.

A set of interventions points or leverage points were identified to change the dynamics of the systems and shift them towards more desirable regimes. Essentially, a structural change of both systems is called for if sustainable livelihoods in the rural areas of the SSA are to be seriously envisaged. Human capital investments present the main opportunity for facilitating escape from poverty by transforming farmers to non-farmers and livestock keepers to non-livestock keepers.

Key words: Poverty traps, sub-Saharan Africa, smallholder agrarian agricultural systems, regime shifts, feedbacks, drivers, leverage points, transformation, and sustainable livelihoods.

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1. INTRODUCTION

1.1. Natural resources and human well-being in sub-Saharan Africa

The rural poor in the sub-Saharan Africa (SAA) depend heavily for their livelihoods on biophysical assets. In the primary production sector as in SSA smallholder agrarian systems, labour productivity (i.e. the quantity of goods produced from each unit of labour input) depends on both the quantity and the quality of supplementary natural resource base available.

Furthermore, specific natural laws of motion govern natural renewable resource dynamics (e.g., logistic-shaped population dynamics of most fauna and flora). Naturally, it follows that if natural resources degrade or improve within a certain range of initial conditions (i.e., natural resource base), labour productivity, and therefore income dynamics, may vary predictably based on initial resource conditions (Barrett 2008). Typically, this means that labour productivity will be high if the natural resource base is in good state. Conversely, if the natural resource base degrades, labour productivity will fall as a result. Ultimately, that gives rise to possibilities for coupled collapse or abundance in human well-being and biophysical resources as renewable natural resources are typically highly nonlinear; that is, a change in the amplitude of an initial condition will in general not result in a proportional change of the response of the system (Perrings 1989; Barrett and Arces 1998).

These dynamics suggest the existence of multiple dynamic equilibria both in nature and in human well-being. Furthermore, there exists at least an unstable dynamic equilibrium between the multiple equilibria which constitutes a critical threshold or "tipping point". Consequently, the direction of well-being can accordingly shift from growth to decline at the critical threshold. Thus, in the event that a given asset base – located below the critical threshold asset holding – cannot sustain decent human well-being (i.e. income) over time, structural poverty traps emerge.

Poverty traps are manifest in smallholder agrarian systems in SSA as the two examples eloquently illustrate. First, Maranya and Barrett (2007) have found a strong positive relationship between soil fertility and household wealth and income measures in Kenya's Western highlands in which, after a few decades' continuous cultivation in annual food crops and as farms gets subdivided in the face of human population growth, the poorer farmers find themselves unable to replenish soil fertility due to seasonal liquidity constraints. As a result, soil nitrogen and phosphorus stocks decline and even past the point where soil rehabilitation

is reasonably easy (critical fertility threshold). Consequently, this drives them into a poverty trap wherein they lack incentive to rehabilitate degraded soils, or even to apply mineral fertilizers to boost current productivity, because the marginal returns to fertilizer application are directly affected by general soil health. Hence, a trap emerges. Second, many studies have observed a positive relationship between *ex ante* wealth and both return on assets and self-insurance capacity which begets stochastic dynamic poverty traps in the east Africa arid and semi-arid lands (ASAL) (Lybbert et al. 2004, Santos and Barrett 2006a). Owing to shocks (drought, raiding...) pastoralists, whose livestock holdings fall below a minimum sustainable livestock size threshold (livestock size above 15 animals), get driven toward towns where stocking densities increase, thereby reducing range availability and thus animal productivity. As a result, reduced protein and energy intake limit pastoralists' strength to undertake arduous treks necessary to reach good pasture and water for their remaining animals. Thence, not only animal productivity keeps declining, but also mortality rates increase with time. Moreover, since there are few non-pastoral options available to stockless and near-stockless pastoralists, the vast majority of whom are illiterate, sedentarization with small herds implies poverty perpetuating, that is, a trap.

That is the predicament in which many of smallholder extensive livestock keeping and annual food production systems in the eastern and southern Africa seem to be trapped, wherein they cannot any longer deliver ecosystem services (ESs) on which local communities rely for their survival. Ecosystem services are goods and services that humans derive from nature (MA 2003). They include provisioning services (e.g. food, feed); cultural services that provide non-material services, such as places for recreation; and regulating services that provide benefits owing to the regulation of ecosystem processes, such as soil formation, nutrient cycling (MA 2005).

Thus, a regime shift analysis of poverty traps in SSA will be based on both annual food production and extensive livestock keeping systems which constitute two stylised cases used for this study.

1.2. Poverty and poverty traps

Poverty is usually defined using two different approaches. Flow-based approaches use income or expenditure as proxy variables to measure human well-being (e.g., the one US dollar per person per day global extreme poverty line). The poverty line of one dollar per day is widely perceived to represent a minimum income or expenditure for meeting basic human needs that divides the more extreme poor from the poor (Wold Bank 2008). Asset-based approaches are

concerned with whether or not the household stock of assets (e.g. land, livestock) is sufficient to generate a satisfactory standard of living over time (Carter and Barrett 2006).

Measurement of poverty distinguishes two different types of poverty. Transitory or temporary poverty is associated with movements into and out of income poverty. Typically, this type of poverty stems from a shock (e.g. droughts, illness, death) that pushes a household into poverty for up to a few years. When the shock has passed, the household rebuilds its stock of assets (e.g. livestock) and moves back out of poverty. In contrast, structural or chronic poverty reflects poverty that persists both in non-shock, shock years, as households control too few assets, and they are not productive enough in using those assets to allow them to escape from poverty without external assistance. In pastoral areas for example, these households are typically the near-stockless and stockless households who are driven out of the range and thus they settle around small towns.

In this study, I used an asset-based approach of poverty and structural poverty because they help to focus on household asset base from which the latter derive their well-being, albeit below a satisfactory standard of living with time.

The economics literature provides several definitions of a 'poverty trap'. Azariadis and Stachurski (2004) define a poverty trap as 'any self-reinforcing mechanism which causes poverty to persist'. This definition is in accordance with structural or persistent poverty on which I focused this study. Typically, poverty traps emerge from complex systems that exhibit multiple dynamic equilibriums in their behavioural repertoires. Both smallholder livestock keeping and agriculture systems are not only complex systems, but they are also conceptualised as social endeavours that are shaped and driven to a great extent by cultural values, market forces, and institutional decisions (Roberston and Swinton 2005). Therefore, agro-pastoral ecosystems ought to be analysed as linked social-ecological systems (Berkes and Folke 1998).

Carter and Barrett (2006) suggest an economic model that explains how poverty traps can emerge. The realised well-being of a given household is subject to stochastic shocks (e.g. drought, health) that affect the stock of productive assets (e.g. production technologies, terms of trade in market exchange) at its disposal. Thus, initial asset holdings limit choice among alternative livelihoods because of lack of complete and competitive financial markets. Consequently, households' asset endowments and restrictions on individuals (e.g., absence of financial credits) typically limit their livelihood choices. As a result, their welfare paths diverge accordingly thereby, suggesting the existence of threshold-based poverty traps. Poverty traps have two basic properties: (i) initial conditions matter, and (ii) transitory shocks

which can have permanent effects, that is, a system can be shifted from one regime to another by a single event or shock.

1.3. Candidate mechanisms of poverty traps

This study analyses poverty traps in both smallholder extensive livestock keeping and agriculture systems in SSA. Globally, three threads of thinking characterise the poverty traps policy discourse in SSA. While Sachs (2005) argues that poverty traps arise because of market failures and resulting asset thresholds, Desoto (2000) emphasises the role of economically dysfunctional institutions. Another line of reasoning stems from conservation management stressing critical thresholds at which recovery from degradation shift markedly suggesting traps (Marenya and Barrett 2007).

The scientific literature suggests a set of candidate mechanisms that could generate poverty traps. First, health of individual family members is the most important biophysical asset the poor control. The capacity to work and to learn is functional on ones physical condition, which depends on one's health status and ability to function in a nonlinear way depending to large extent on nutrition levels. That is, there are multiple equilibria in physiological functioning suggesting that health shocks can negatively affect human labour power if one's ability to work is below the strict minimum, thus trapping households into persistent poverty (Krishna 2006).

Second, a lack of income in smallholder agrarian systems in SSA impedes the generation of cash necessary to meet both current consumption needs and investment requirements that will maintain or increase future productivity. Thus, financial liquidity constraints can lead to underinvestment, both in natural-resource conservation or improvement (Barrett *et al*. 2002; Antle *et al*. 2006) and in education (Loury 1981), causing intergenerational transmission of poverty.

Third, uninsured risk can often cause episodic over-exploitation of natural resources, especially when the resource base cannot support increasing pressure (Barrett and Arcese 1998). That situation leads to soil nutrient depletion, that is, the net loss of plant nutrients from the production system owing to higher nutrient outputs (through crop harvest, erosion, etc) than inputs (e.g. through manure, fallow, mineral fertilizer), resulting in a negative nutrient balance in SSA (Drechsel *et al.* 2001). Furthermore, human population growth also exerts high pressures on assets such as land and livestock, thereby increasing their partition, which can reinforce a poverty-trap mechanism (Barrett 2008).

Fourth, weak institutions lead to resource degradation (Barrett *et al.* 2001) and

impoverishment (De Soto 1989; 2000) because of failing to setting and enforcing rules (Gibson *et al*. 2005). Lastly, coordination failures among several levels of social aggregation can undermine incentives to accumulate and invest in productivity improvements (Barrett and Swallow 2006).

1.4. Regime shifts and resilience

Scheffer (2009) defines a regime shift as "a relatively sharp change from one regime to a contrasting one, where a regime is a dynamic 'state' of a system that has its characteristic stochastic fluctuations and/or cycles". Biggs *et al*. (2011) provide an operational definition of regime shift that conceptualises it as 'any large, abrupt persistent change in critical ecosystem services that last long enough to have significant impacts on human economies and societies'. On the other hand, Walker and Salt (2006) define "resilience" as 'the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. From these definitions, it emerges that a dynamic system can have several regimes in which it can settle under the same external conditions.

Complex systems as social-ecological systems have multiple feedback processes that can produce multiple self-reinforcing states that are called regimes or alternative dynamic stable states (Walker and Mayers 2004). In each of the regimes or alternative dynamic stable states, the system is attracted to or repelled from an equilibrium point, leading to different stability properties of the system (Bossel 2007). Thus, the interactions of the systems maintain or erode the resilience of these regimes.

Meadows (2008) defines a feedback loop as a "closed chain of causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow to change the stock". Two different kinds of feedback exist. A positive feedback loop, referred to also as a reinforcing feedback loop is one that reinforces whatever direction of change is forced upon the system and is marked with (R) or (+). A negative feedback loop (called also balancing feedback loop) is one that reverses whatever change is imposed upon the system and it is marked with (B) or (-) signs. The interactions of these different types of feedbacks produce regimes (Bennett *et al*. 2005).

Stability properties of the system are influenced by inputs and parameters. These have the common property that their values are independent of the system, meaning that they are determined by some external agent or process over which the system has no control (Bossel 2007). These are referred to in this paper as "drivers". The Millennium Ecosystem

Assessment (MA) defines a driver as “any natural or human-induced factor that directly or indirectly causes a change in an ecosystem” (MA 2005). Two types of drivers are distinguished. A direct driver influences ecosystem processes, while an indirect driver operates more diffusively, by altering one or more direct drivers (Nelson 2005). The MA identifies direct drivers as for instance climate change, plant nutrient use, land conversion leading to habitat change, and invasive species and diseases, while the main indirect drivers encompass demographic, economic, socio-political, cultural and religious, and science and technology factors.

Either system change can occur through an alteration originating from external drivers or from within a feedback connection that defines its stability properties. System change is a neutral term in that it can imply either improvement or deterioration of the state of human society or environment. Systems can usually absorb small perturbations in their environment by adjusting certain of their state variables (i.e. variables that define the state of the system at any given time) through feedback control processes, leaving the behaviour-determining structure unchanged.

A resilient system is one that is able to absorb disturbance and stay in the same regime. However, it worth noting that ‘resilience’ in and of itself is a free concept in that it is not necessarily a good thing from an anthropocentric viewpoint. For example, undesirable configurations of a system (e.g. soil degradation, economically dysfunctional institutions) can be very resilient in that self-reinforcing feedbacks maintain the same controls on the function of the system over time (Walker and Salt 2006). In such cases, it might be more appropriate to redefine the very making up of the system by transforming it. That means that societies or communities invest in the ability to reorganise around a different range of goods and services that the new regime makes possible (Anderies and Norberg 2008). Thus, transformation requires a structural change of the system of interest. This is carried out by seeing where both actions and changes in the systems’ behaviour-determinant structure can lead to significant, enduring improvements (Senge, 1990). In other words, transformation can be achieved by finding leverage points (LP) of change.

These LPs are points of change at which interventions could either prevent destructive change in a system, or guide it onto another path, or even evoke and enhance change where necessary. System change that leads to transformation can stem from either drivers or variables that alter system structure or feedbacks, and therefore system behaviour. Meadows (2008) suggests a list of potential leverage points that coarsely divides into physical and control parts of the system. The physical part of the system encompasses among other

constants and parameters (i.e. rate of fertility degradation), the size of stabilizing stocks relative to their flows (i.e. soil plant nutrients stocks), stock-and flow structures, and the lengths of time relative to the rates of system changes (i.e. delays in feedback process). Physical structure is rarely a leverage point, because it is not easy and quick to change, therefore the leverage point is in proper design. As for the control part, it comprises the strength of the feedbacks relative to the impacts they are trying to correct (i.e. balancing feedback loops), the strength of the gain of driving loops (i.e. reinforcing feedback loops), information flows, rules, and self-organisation, goals, paradigms and transcending paradigms. Unlike physical structure, the control part provides more leverage points.

1.5. Purpose of the study and choice of case studies

This study analyses poverty traps in smallholder extensive livestock systems in the east Africa and annual food production systems of SSA, using a regime shifts approach.

Smallholder livestock keeping and agriculture systems constitute the two main economic activities in SSA rural areas. Thus, the choice of the two case studies was grounded in the fact that a large number of rural households still depend on these activities for their livelihoods.

The main purpose of this study is to integrate both regime shifts and poverty traps concepts in the analysis of smallholder agrarian systems in SSA in order to gain insights into the dynamic behaviours of the latter. Taking stock of insights gained from the systems analysis, this study furthermore aims at contributing to the devise of informed management interventions intended to better shift these systems from low-level towards higher-level of well-being.

I chose the regime shifts framework to analyse poverty traps because it integrates both the dynamics of human well-being (e.g. income or expenditure) and the underlying dynamics of natural renewable resources from which the former originates in order to provide a dynamic holistic view of the system. The regime shift framework permitted me to perform an assessment of relevant regimes of smallholder agrarian systems in SSA by defining their essential structures, therefore their intrinsic dynamics, and their external driving forces that contribute to their current systems states. The regime shift framework allows an assessment that aims at better understanding and managing change in real social-ecological systems by readily focusing on dynamics of both human well-being and renewable natural resources from which the former originates.

Three research questions guided this study and are formulated as follows:

1.What self-reinforcing mechanisms sustain poverty traps in rural areas in eastern and southern Africa?

2. What are the key drivers of change in these systems?

3. What leverage points could enable breaking out of these poverty traps by weakening or breaking feedbacks?

2. METHODS

Despite recent innovations, the economic perspective using a flow-based approach centred on income or expenditure of households at particular point in time has dominated the assessment of poverty in SSA communities.

This approach misses out interacting relationships between human well-being (i.e. income or expenditure) and renewable natural resources that define dynamically the status of a social-ecological system at any point in time.

In contrast, the Regime Shift Database (RSDB) provides a practical and operational framework for assessment that aims to better understand and manage change in real social-ecological systems.

Therefore, I applied the latter to two generic stylized case studies from SSA, notably smallholder extensive livestock keeping in east Africa and smallholder agricultural annual food production systems in order to assess their relevant regimes by defining both their essential structures and external driving forces that contribute to their current systems states.

2.1. Case studies

Smallholder agrarian systems, notably extensive livestock keeping systems and annual food production systems constitute two main livelihoods for the majority of the poor rural in sub-Saharan Africa. In fact, they either raise livestock or cultivate crops for subsistence and use the surplus for cash to cover the cost for basic needs (e.g. food, medicine, school fees).

However, there exist a wide variety of smallholder systems in SSA that differ in their resource endowment, livelihood strategy, aims and long-term aspirations. This study will be specifically limited to two types of stylized cases, notably smallholder extensive livestock keeping and annual food production systems of eastern and southern parts of Africa. In fact, while smallholder extensive livestock productions serve as the bedrock of livelihoods and culture in the ASAL regions where agricultural production is not possible owing to harsh

climatic conditions, most smallholders in southern parts of Africa practice annual food production as their main livelihood.

a. Smallholder extensive livestock keeping systems

The arid and semi-arid lands (ASAL) of East Africa are characterised by harsh climatic conditions. Rainfall in these areas varies and fluctuates between 25 mm and 600 mm, as much in time as in place (Grahn 2008). The ASAL lands constitute part or whole landscapes of SSA countries, notably Ethiopia, Kenya, Somalia, Sudan, Tanzania, and Uganda. Livestock keeping is the core economic activity in the ASAL regions (Hogg 1992), but it is only part of the income generation. Other income stems from non-pastoral activities such as trading, running business, working for a daily wage or salaried employment, remittances but also food aid (Little *et al.* 2007).

Two distinct modes of livestock keeping are distinguished in the ASAL of east Africa. First, sedanterised livestock keeping is characterised by one or two cows kept by sedanterised households who have turned to cultivation while keeping a milk cow. Destitution and localised land degradation (McPeak and Barrett 2001) appear alongside one another, and are magnified by human population growth (CBS/MPND 2004) in an area that is subjected to declining grazing lands. Second, migratory livestock keeping is based on transhumant grazing of large livestock sustained by long-distance treks to places that have abundant water and forage (Lybbert *et al*. 2004). That mode of livestock keeping is associated with relatively higher standards of living and social status.

In the ASAL of east Africa, livestock keepers have poor access to basic social services, notably health care, and education (Halderman 2004). Social mutual aid mechanisms that used to help livestock keepers who suffer severe livestock losses appear to have declined. That is because many households are no any longer able to participate, and the incentives to provide transfers to the poor have sharply declined (Huysentruyt *et al*. 2009; Santos and Barrett 2006).

b. Smallholder agriculture systems

While agriculture accounts for more that 25 % of the gross domestic product (GDP) of most SSA countries, it is the main livelihood for at least 65 % of Africa's population of 750 million (Henao and Baanante 2006). In fact, 90 % of agricultural production is derived from smallholder farms whose average size is 1.6 ha (Nagayets 2005), but average size can be smaller than 1 ha in high population density areas.

Soil fertility depletion is considered as the major biophysical factor that compromises per

capita food production on the majority of African small farms (Sanchez *et al.* 1997). Resulting environmental degradation is a common feature in most SSA countries' landscapes, especially where smallholder agriculture is practiced under increasing human population pressure and scarce arable land. Typically, that leads to a shortening of fallow periods and expansion of cropland areas into unsuitable environmental situations such as steep slopes. This pattern goes on despite the emergence of agro-ecological practices and widespread efforts to introduce sustainable land management technologies on small farms (Liniger and Critchley 2007).

Market infrastructures such as rural roads and postharvest facilities are at best scrambling but in most cases are almost inexistent in rural areas, which limit market access for outputs and inputs (e.g. fertilises, phytosanitary products) for the majority of small-scale farmers (FAO 2005).

2.2. The Regime Shifts Database framework

The Regime Shifts Database (RSDB) provides a practical and operational framework for applying the regime shift concept. As an approach, it aims to inform management of real social-ecological systems by identifying regime shifts that have large impacts on ecosystem services at time horizons that are relevant to human societies.

The RSDB provides a framework for assessment that aims not only to better understand and manage change in real social-ecological systems but also to compare change across different ecosystems types. This is done by making information on regime shifts available online for scientists, students, and practitioners interested in management and functioning of different systems.

Typically, the RSDB template is organised in two different parts. The first part provides an overview of a particular regime shift. It comprises a set of elements that are to be recorded for each regime shift, notably regime shift name, contributors, and a summary of the regime shift. As to the second part, it provides in-depth information on the particular regime shift. That consists of detailed descriptions of the regime shift considering a set of factors notably, alternate regimes, reinforcing feedbacks, drivers of the regime shift, impacts on ESs and human well-being, and finally options for managing or preventing the regime shift. The assessment of each regime shift also includes a description of the ecosystem type and land use under which it occurs, its level of reversibility and the confidence level of the information.

The rest of this section describes how I actually used the regime shift framework to analyse the two case studies.

To assess the two case studies, I read a number of different materials that provided me with relevant information on small-scale agrarian systems in SSA. These materials were diverse in their nature in order for me to get a broad view on the systems I was interested in. I consulted scientific papers including economic and natural resource management literature which are related to poverty traps, Apart from those that are already cited in the plain text, I supplemented extra documents (marked * in the reference list).

Furthermore, I read academic theses that focus on small-scale agricultural systems together with working papers and reports stemming from well-known international institutions that are closely involved in many diverse development schemes in SSA. Typically, information contained in these documents constitutes descriptive or verbal models, i.e. a description of behaviour from observation of a given system. Experts, scientists, and actual actors in, or operators of, the systems produce this information in order to develop a model of the relevant system structure. Therefore, I gathered valuable behavioural data on the two systems. Subsequently, I developed structural or explanatory modelling of the systems under inquiry through graphical representation in the form of casual loop diagram (CLD) for their analysis. Furthermore, through literature review I synthesised information on both ecosystem services and their implications on human well-being associated with smallholder livestock keeping and agriculture systems in the SSA.

2.3. Systems modelling

The complete process of systems analysis from model development to simulation to behavioural analysis and system design runs through several stages ranging from development of the model concept, development of the simulation model, simulation of system behaviour to policy analysis design.

The purpose of developing models of the two cases under study, notably both smallholder extensive livestock keeping and agricultural systems, was twofold and was limited to the development of the model concept. Essentially, the development of model concepts consisted of both revealing behaviourally relevant structures of the two systems – in particular their feedback structures – and representing dominant relationships among their system components in the form of CLDs in order to derive a first qualitative analysis of system behaviours they represent.

A special attention was paid to ensure that structural validity of the models was respected. That was done by making sure that the models have the same number of essential state variables which are connected by the same feedback structure as in the original systems.

Through the in-depth literature study I carried out, I identified both different components that make up each of the systems and their functional dependencies. By doing so, I looked closely at the individual elements and their particular role and function in these different components. Furthermore, I identified two categories of elements typical to dynamical systems. First, I defined input quantities, i.e. system parameters and exogenous inputs also called drivers. I will use the term “driver” each time I refer to exogenous inputs in this paper. Secondly, I defined the other category, which encompasses “state variables” which constitutes the coordinates of the system at any given time. Essentially, the differentiation between the two categories of system elements is of fundamental significance for system representation in graphical form, as the two categories of elements have distinctly different effects on system behaviour.

From verbal models and general system-theoretical knowledge, I extracted the system elements (state variables) and their information-based relationships to develop the casual loop diagrams (CLDs) of the two systems. State variables are the smallest set of endogenous time-varying variables that allow, for a given model purpose, the complete description of the system state (Bossel, 2007). They were chosen following a fundamental criterion which is representativeness of the system state of interest.

Thereafter, I used the software Vensim PLE (Ventana Systems, 2010) to build the models of the two systems. In a systematic way, I built the structures of different components of the system one at a time before looking at their functional dependencies through vital connections that link one another. Therefore, I followed a systematic process, which is outlined as follows:

To start with, I placed all defining “state variables” of the given system in the build window of the Vensim PLE. These variables are represented by the “nodes” of the diagram and marked by their respective names.

I made sure those variables that are strongly connected by mutual influences be drawn next to one another to avoid much crossing-over of influence arrows.

Then, I represented influences between variables by arrows heading in the direction of influence. Typically, an arrow pointing from one state variable, i.e. “node”, to another state variable (node) means that the former influences the latter.

From the verbal model, I derived the sense of influence relationship between two given state variables using the plus or minus signs (Sterman, 2000). The plus sign (+) was used to indicate that two state variables engaged in a link will change in the same direction. That means, for example as A increases B increases; as A decreases B decreases as well. By contrast, a change in the opposite sense is displayed by a minus sign (-), i.e. as A increases B

decreases; as A decreases B increases. Furthermore, the derivation of sense of influence relationship is done under *ceteris paribus* conditions, i.e. all things held equal. Completing all links among the variables involved in a component, I obtained a closed chain of causal connections called feedback loop. Subsequently, I defined the sense of the closed chain of causal connections by counting the number of minus signs it contains. Thus, as a whole, the feedback loop will be either positive (R) if the loop contains an even number of minus signs, or negative (B) if it contains an odd number of minus signs (Bossel, 2007). The feedback sign was shown inside of the loop.

I repeated the above systematic process with all system components. Consequently, the process resulted in having different feedbacks loops structures of which the system is composed. In essence, this represents the underlying system structure from which the behaviour of the system can be analysed.

2.4. Regime shift analysis

I performed the systems analysis of the two systems of interest in different stages. First, I referred to the conceptual framework of the MA (MA 2003) in order to determine data necessary to establish the existence of alternative dynamic regimes within each studied system. Essentially, the data were related to both ecosystem services (provisioning, regulating, cultural and supporting) and human well-being attributes, notably health, livelihood, economic activity, security of housing, cultural values and social conflicts.

Second, I performed resilience analysis in order to establish the relationship between system structure and system behaviour. To start with, I described the functioning of all feedback loops that make up the system structure one at a time in order to grasp both their intrinsic behaviour over time and their specific function. Then, I identified critical influence relationships that not only connect feedback loops of the system but also condition their functional dependencies. I did that to eventually determine the integrity of the system structure in what Meadows (2008) refers to as “System-ness”, which typically reveals the intrinsic behaviour of the system.

Subsequently, I first identified relevant influences from the system environment that affect the system structure. These influences emanate from system elements referred to as input quantities that I called “drivers”. Then, I explicitly specified their points of influence on key feedback loop structure of the system. Thereafter, I described how the identified drivers actually influence the behaviour over time of the affected feedback loops. It is worth noting that in the CLDs, drivers cannot be influenced by other system elements, that is, there are no

feedbacks from state variables to drivers.

Lastly, I identified leverage points through a three-step approach. First, I looked at dominant influence relationships that connect different feedback loops implicated in the system structure in order to assess how they either strengthen or weaken the latter. Second, I assessed the sensitivity of single variables, be it drivers or state variables, i.e. I looked at their specific function and role in the system functioning as a whole. Third, taking stock of insights gained through the two first steps I confidently determined points of intervention that could substantially change the system behaviour.

3. RESULTS

This section provides the results of the regime shift analysis. **Section 3.1** describes changes in ecosystem services and human well-being in the alternate regimes of the two systems. **Section 3.2** contains a description of the proposed feedback mechanisms that maintain poverty traps. **Section 3.3** provides a description of the key drivers that cause the systems to shift between alternate regimes and **section 3.4** gives the analysis of the systems' structure in the view of finding leverage points for change.

3.1. Alternate regimes and ecosystem services

a. Sedentary livestock keeping systems

My analysis of the literature shows that extensive pastoral production systems in the ASAL lands in eastern Africa exhibit two alternate regimes, which are characterised by two contrasting dynamic equilibriums. While the migratory pastoralism regime is associated with high welfare equilibrium characterised by large herd sizes, the sedentary livestock keeping corresponds to a low level of welfare characterised by small herd sizes of one or few animals. A dynamic threshold constituting an unstable regime separates the two alternate stable regimes at which point household wealth dynamics bifurcate towards either stable regime.

The results of the assessment of the ecosystem services associated with the two alternative stable regimes of extensive livestock keeping systems in the ASAL in eastern Africa are synthesised in the table 1**.**

Table 1. Ecosystem services associated with both migratory and smallholder livestock keeping systems in the ASAL Africa.

Regimes	Ecosystem Services		
	Regulatory	Provisioning	Cultural
Migratory livestock keeping	- Primary production - Fertile soils - Nutrient Cycling - Carbon sequestration - Genetic diversity - Erosion control	- Water availability - Pasture - Trees - Livestock & livestock products - Fibre	- Customary way of living
Sedentary livestock keeping	- Impairment of the above services	- Sharp decline in the above services	- Loss of cultural values

While a sharp decline in provisioning services is noticeable from the assessment, a decrease in regulating services is also manifest. Moreover, cultural services provided by mobile pastoralism are lost because of the shift towards sedentary livestock keeping. These declines in ecosystem services ultimately induce changes in human well-being.

Two contrasting outcomes emerge from the assessment I performed on human well-being derived from ecosystem services provided by each regime. The migratory livestock-keeping regime indicates a good performance in most of the different attributes of human well-being, notably food and nutrition, health, livelihood and economic activity, security of housing and infrastructure, cultural values, and social conflicts.

Conversely, sedentary livestock keeping exhibits a decline in the level of the same attributes. Furthermore, while the shift from migratory livestock keeping regime to sedentary livestock keeping increases social conflicts over natural resources (e.g. water, land) within and between local communities, cultural values associated with migratory livestock keeping are lost as a result.

b. Small-holder agricultural systems

Soil fertility in smallholder agricultural production systems displays two alternative stable regimes defined by levels of soil organic matter (SOM). In fact, soil fertility dynamics diverges towards two contrasting regimes, which are associated with different management practices leading to differing human welfare status. While a sustainable soil fertility regime results from good management of the soil nutrient base, a degraded soil fertility regime, that is, unsustainable soil fertility regime results from plant nutrients export mainly through harvesting without any nutrient replenishment.

The two regimes are separated by an unstable regime which is characterised by a labile pool of SOM and related soil nutrients. At this soil fertility threshold, the dynamics of the system

bifurcates markedly towards either of the two alternative regimes.

The results of the assessment of ecosystem services associated with both sustainable agriculture and smallholder agriculture systems are synthesised in table 2. These ecosystem services split into three different categories, notably regulating, provisioning services, and cultural services.

Table 2. Ecosystem service availability in alternate regimes of soil fertility system in smallholder agrarian systems in SSA.

Regimes	Ecosystem Services		
	Regulatory	Provisioning	Cultural
Sustainable agriculture	- Nutrient cycling - Soil fertility - Soil hydraulic properties - Primary production - Carbon sequestration - Erosion control - Biodiversity	- Food and cash crops - Food and non-food provided by surrounding landscapes	-
Unsustainable agriculture	- Impairment of the above services	- Decline in provision of above services	-

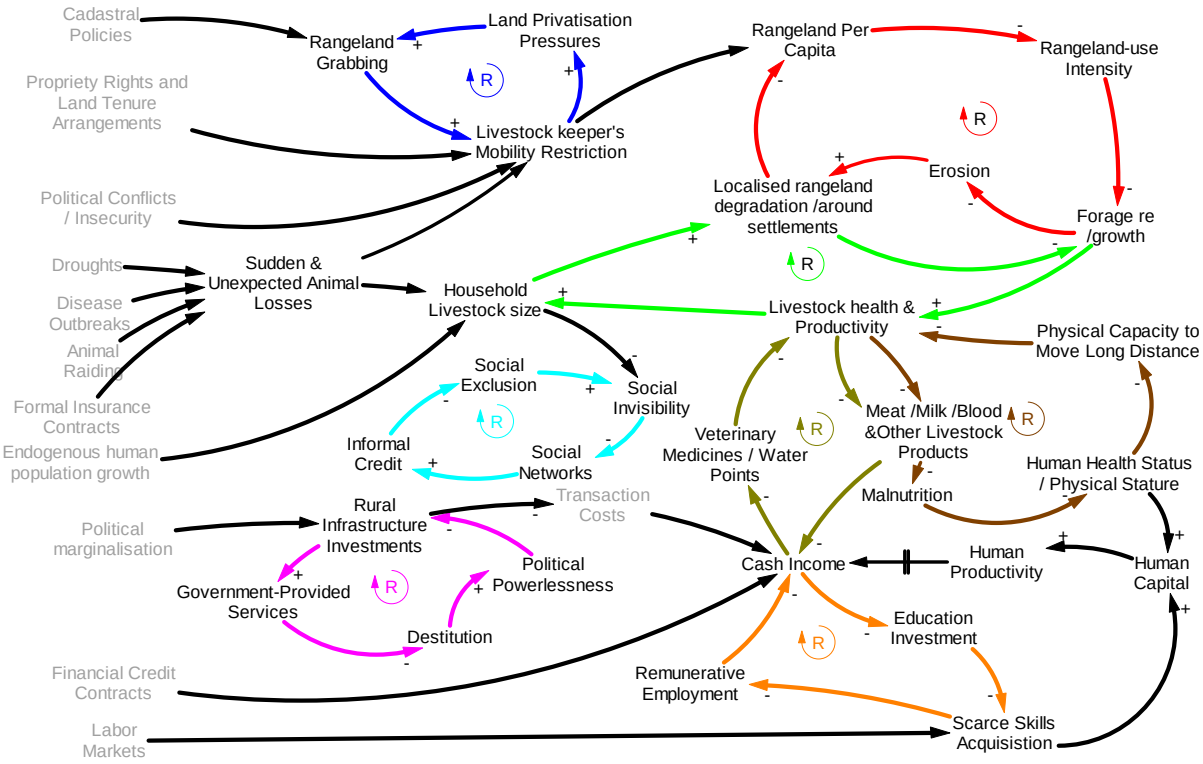
It emerges from table 2 that sustainable agriculture systems provide an abundant flow of both regulating and provisioning ecosystem services, whereas smallholder agriculture systems show a sharp decline in provisioning services and an impairment of the same regulating services.

The resulting outcomes of the assessment I undertook on human well-being, derived from ESs provided by both sustainable agriculture and smallholder agriculture systems show contrasting pictures. While sustainable agriculture systems exhibit high levels in most of the attributes capturing human well-being, notably food and nutrition, health, livelihood and economic activity, smallholder agriculture systems show a decline in almost of the same attributes.

3.2. Key Feedbacks

Essential behaviour-determinant structures of both the sedentary livestock keeping and the smallholder agriculture are respectively portrayed in the figures 1 and 2.

The analysis of figure 1 reveals the essential structure of the smallholder livestock keeping system that consists of a set of eight different components that constitute the key feedback loops of the system. Of the eight feedback loops, six of them are tightly clustered together while the two remaining, notably political powerlessness and mobility feedback loops, seem more or less isolated.



Legend:

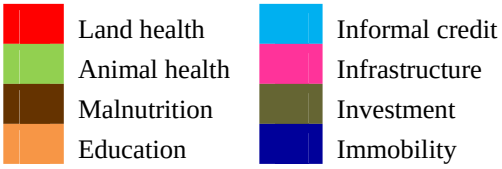
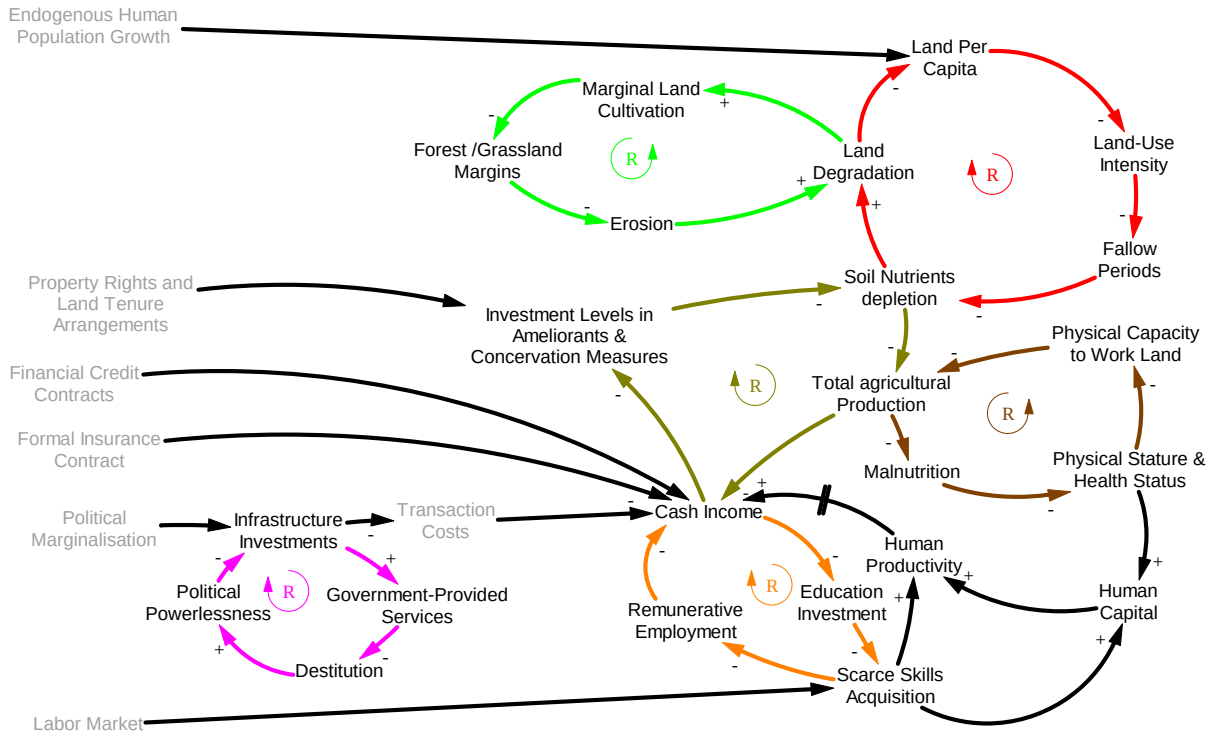


Figure 1. Casual loop diagram of smallholder livestock keeping systems.

Similarly, figure 2 depicts six essential key constitutive feedback loops of the smallholder agriculture system. The feedback loops that form different components of the system closely connect to one another, except for the infrastructure feedback that appears to be somewhat isolated from the rest.

The two casual loop diagrams (CLDs) in figures 1 and 2 consist of different reinforcing feedback loops that represent smallholder sedentary livestock keeping and agriculture systems. Thus, each sub-system has both its own purpose and distinct constitutive elements. The two CLDs share a set of four feedback loops, notably investment, malnutrition, education, and infrastructure. However, although the investment feedback loop has the same purpose in the two systems, elements that compose it are distinct to each system. Based on their particular structure, I inferred the intrinsic behaviours of different key feedback loops across both systems as follows:



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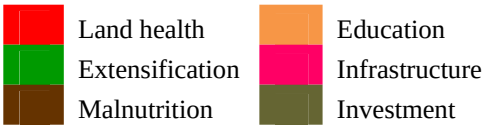

Figure 2. Casual loop diagram of smallholder agriculture systems.

a. Investment

This feedback loop contains four distinct variables, notably livestock health and productivity, livestock products, cash income, and veterinary medicines/water points for livestock systems and soil nutrient depletion, total agricultural production, and investment levels in ameliorants and conservation measures in agriculture systems.

In smallholder livestock keeping systems, a lack of cash income prevents investments in veterinary medicines and water points, which negatively affects livestock health and productivity. As livestock health and productivity decrease, livestock product outputs (i.e. meat, milk, blood) decrease as well. This fails to show surpluses to be sold in order to gain income cash, without which there is no investment in veterinary medicines and water points, and the cycle repeats.

With regard to smallholder agriculture systems, owing to lack of cash income prevents investments in ameliorants and conservation measures, which fails to prevent soil nutrients

depletion. Nutrient depletion decreases total agricultural production with time, which fails to show surpluses, which depresses cash income without which investment in ameliorant and conservation measures cannot be undertaken. The cycle repeats.

The four variables are engaged in four influence relationships in a reinforcing feedback loop so that any decrease in cash income amplifies via the feedback in the direction of further decrease in investment.

b. Malnutrition

The feedback loop contains four variables for each system, notably livestock health and productivity, livestock products, malnutrition, health status/physical stature, and physical capacity to move long distance for livestock systems, and total agricultural production, malnutrition, health stature/physical stature for agriculture systems. Meagre livestock products (i.e. meat, milk, blood) and agricultural production negatively increases household members' malnutrition, which decreases human health status, and physical stature, which depresses physical capacity to work land/move long distance with livestock. As a result, both livestock products and agricultural production outputs decrease, which negatively increases malnutrition and the cycle go on.

The resulting sign of the whole chain is positive, suggesting that any decrease in total system's outputs (i.e. agricultural food or livestock products) will be self-reinforced through the feedback loop in the direction of further increase in malnutrition.

c. Education

The feedback loop consists of four variables, notably cash income, education investment, scarce skills acquisition, and remunerative employment that are engaged in a chain of causal connections. From the loop structure, it emerges that the original perturbation in the direction of decreasing in cash income amplifies via the feedback in the direction of further income decrease, therefore less scarce skills acquisition. Lack of cash income prevents rural households from investing in education, which prevents household members from acquiring scarce skills. Without scarce skills, household members cannot afford remunerative employments, which jeopardises their abilities to generate alternative cash income without which they further cannot afford education investment. Thence, the cycle repeats over time.

d. Infrastructure

Four variables make up this loop, notably infrastructure investment, government-provided services, destitution, and political powerlessness. Destitution increases political

powerlessness, which decreases rural infrastructure investments. Rural infrastructure investment increases government-provided services without which destitution increases and the cycle repeats itself. As a result, four causal connections result from the feedback loop that reinforces the original decrease in infrastructure investments (i.e. political neglect), which charts a pattern of further decrease in infrastructure investment.

e. Immobility

The feedback loop consists of four variables, notably rangeland grabbing, livestock keeper's mobility restriction, and land privatisation pressures. Livestock keeper's mobility restriction increases land privatisation pressures, which increases rangeland grabbing which in turn further increases livestock keeper's mobility restriction. From the structure of this loop, any increase in livestock keeper's mobility restriction amplifies through the feedback in the direction of further increase mobility restriction.

f. Informal credit

The feedback loop involves four variables, notably social invisibility, social networks, informal credit, and social exclusion. Social invisibility prevents livestock households from accessing social networks from which emanate informal credits, which increases social exclusion that increases social invisibility. The particular structure of the feedback loop shows that any increase in social invisibility amplifies through the feedback loop resulting in further increase in social invisibility.

g. Animal health

This feedback implicates four variables, notably household livestock size, localised degraded rangeland use, and livestock health and productivity. Household livestock size decreases as localised degraded rangeland use increases, which decreases forage re-/growth, which in its turn depresses livestock health productivity without which household livestock size keeps on decreasing with time.

In fact, these four variables are connected to one another by causal connections, which result from the particular structure of the chain in a decline over time in household livestock size through animal health deterioration.

h. Rangeland and agricultural land health

These two loops comprise five variables each that are involved in causal relationships. With regard to the rangeland feedback, reduction in rangeland per capita increases rangeland-use intensity, which decreases forage (re)growth and increases erosion that, in its turn,

increases localised rangeland degradation, which by implication decreases rangeland per capita, and thus the cycle repeats.

Concerning the land health feedback, a decrease in land per capita increases land-use intensity, which decreases fallow periods, which contributes to an increase in soil nutrients depletion, which increases land degradation that, in its turn, decreases land per capita, and the cycle goes on.

The resulting structures show that any reduction in either rangeland per animal capita animal or agricultural land per human capita will be self-reinforced via the feedback in the direction of further rangeland, and agricultural land per animal/human capita decrease.

i. Extensification

This feedback loop contains four variables, notably land degradation, marginal land cultivation, forest/grassland patches, and erosion. Land degradation triggers marginal land cultivation, which decreases forest/grassland patches that, in its turn, increases erosion, which in turn increases land degradation. The structure of the feedback loop indicates that any reduction in marginal land amplifies through the feedback in the direction of further decrease in forest/grassland Patches. The cycle repeats itself with time.

3.3 Drivers

Key drivers of smallholder livestock keeping and agriculture systems identified from figures 1 and 2 are summarised in the table 3.

Table 3: Key drivers of smallholder livestock keeping and agriculture systems in SSA.

Drivers	**Systems**	
	Sedentary livestock keeping	**Smallholder agriculture**
Direct drivers	-Droughts -Disease outbreaks -Animal raiding	-droughts
Indirect drivers		
Demographic	-Endogenous human population growth	-Endogenous human population growth
Socio-political	-Property rights and land tenure arrangements -Political conflicts -Political marginalisation -Cadastral policies	-Property rights and land tenure arrangements
Economic	-Transactions costs -Formal financial credits -formal insurance -Labour markets	

It emerges from table 3 that although the two systems share most key drivers, they also have some that are unique. Droughts for example are climatic events that drive the two systems but with different results. While they can shift livestock keeping systems from one regime to another, they do not contribute directly to regime shifts in smallholder agriculture systems. Furthermore, drivers influence the system behaviour through their points of impact on the respective systems that make up smallholder livestock keeping and agriculture systems.

With regard to smallholder livestock keeping systems, social political drivers except for political marginalisation, reduce livestock keeper's mobility. As a result, the response of the sub-system constituted by the mobility feedback loop is the amplification of the immobility of livestock keepers.

Droughts, disease outbreaks along with animal raiding lead to sudden and unexpected animal losses. Animal losses influence the intrinsic dynamics of both the immobility feedback loop and that of the informal credit feedback loop by self-reinforcing their respective responses.

Lack of formal insurance contracts leads to the self-reinforcement of both the immobility and informal credit feedback intrinsic dynamics, failing to cushion livestock keepers against sudden and unexpected animal losses.

Concerning smallholder agriculture systems, endogenous human population growth decreases land per capita. The response of the land health loop is such that the decrease in land per capita is amplified through intrinsic dynamics of the land health feedback loop.

Property rights and land tenure arrangements lead to a disincentive to investing in soil technologies. Self-reinforcement via the investment feedback loop drives the system further in the direction of less investment in soil ameliorant technologies.

Political marginalisation drives the infrastructure feedback loop in both systems by self-reinforcing its intrinsic dynamics less investment in rural infrastructures over time. Together with financial credit contracts and labour markets they influence both investment and education feedback loops. Through cash income depression, intrinsic dynamics of both the investment and education feedbacks are amplified further in the direction of respectively less investment in productive assets and less investment in education.

3.3. Leverage points

Analysis of the figures 1 and 2 reveals that while different feedbacks are involved, they feed into one other and self-reinforce one another through strong influence relationships connecting them. I identified a range of critical variables that not only connect different

feedbacks but also critically influence their respective dynamics and constitute places where change will influence the system structure and thereby system behaviour. The connecting variables together with feedbacks are summarised in the table 4 and 5.

Table 4. Variables connecting smallholder agriculture system feedbacks in SSA.

Connecting variables	Feedbacks
Land degradation	Extensification - Agricultural land Health
Soil nutrients depletion	Investment- Agricultural land Health
Soil nutrients depletion & total agricultural production	Investment- Agricultural land health-Malnutrition
Transaction costs	Infrastructure-Investment-Education
Cash income	Investment- Education

It is apparent from table 4 that three connecting variables play a key role in linking different feedbacks involved in smallholder agriculture systems. While land degradation connects the extensification feedback to the agricultural land health feedback, soil nutrient depletion links the investment feedback to the agricultural land health feedback. Furthermore, soil nutrient depletion variable together with total agricultural production connect the investment, agricultural land health and malnutrition feedbacks to one other.

The analysis of table 5 reveals that livestock keeper's mobility restriction variable links three feedbacks, notably immobility, animal health, and rangeland health.

Table 5. Variables connecting smallholder livestock keeping systems' feedbacks in SSA.

Connecting variables	Feedbacks
Livestock keeper's mobility restriction	Immobility – Animal health – Rangeland health
Sudden & unexpected animal losses	Immobility – Animal health
Livestock keeper's mobility restriction & rangeland per capita	Immobility – Animal health – Rangeland health
Household livestock size	Animal health – Rangeland health – Informal credit
Livestock Health & productivity	Animal health – Investment – Malnutrition
Transaction costs	Infrastructure – Investment – Education
Cash income	Investment – Education

Sudden and unexpected animal loss links both immobility and animal health feedbacks. Furthermore, livestock keeper's mobility restriction together with rangeland per capita connects three of the feedbacks involving the immobility feedback and animal health as well as rangeland health feedbacks. Household livestock size links a set of three feedbacks involving animal health, investment and informal credit feedbacks whereas livestock health and productivity connects animal health, investment, and malnutrition feedbacks. Finally, while transaction cost links the infrastructure feedback to investment and education feedbacks via cash income, the latter connects both former feedbacks, which is, investment and education feedbacks.

Table 6. Leverage points to change systems' behaviours towards desirable path.

Leverage points	Smallholder livestock keeping systems	Smallholder agriculture systems
Unique	- Informal social livestock insurance	-
Common	- Economic drivers: formal insurance, financial contracts and labour markets - Property rights and land tenure arrangements - Education - Human Health- Nutrition - Good governance: enabling institutions and policies	

The determination of both connecting variable and driver effects helped me to identify a range of different leverage points that are summarised in the table 6. It is apparent from table 6 that the two systems share most of leverage points, except for informal livestock insurance that is unique to livestock systems.

4. DISCUSSION

Before discussing my findings, it is important to underscore that this work is based on an analysis of model systems and not on any real-world systems. Thus, their validity remains confined to the purpose of the models, which is the recognition and representation of the essential system structures, that is, feedbacks of the two studied systems in view of analysing their behaviours in order to gain insights into how to better to inform their management.

This discussion is organised as follows. In section 4.1**,** I discuss insights gained with relation to how feedback mechanisms, drivers and leverage points operate. I then discuss the practical significance of the leverage points relative to challenges that are erected by some key indirect drivers in real-world systems in section 4.2. To close the discussion part, I will finally reflect on the regime shift framework in section 4.3.

4.1. Feedbacks, Drivers, and Leverage Points

This section uses insights gained from the model systems that I developed. Thus, the discussion will revolve around two main points. First, how influence structures, that is, feedback loops of the systems, determine system behaviours. Second, how drivers influence system behaviours and the impact of identified leverage points on the influence structures as a result of system structure change in order to provide hints concerning potential management actions to altering the model systems dynamics.

Q 1. What self-reinforcing mechanisms sustain poverty traps in rural areas in southern Saharan Africa?

My findings suggest that the overall dynamics of smallholder livestock keeping and agriculture systems are function of the action of three critical factors, notably land per capita, infrastructure investment, and livestock keeper's mobility restriction. In fact, these factors determine the relative strength of different feedbacks of which they are part. Thus, the consequences for the systems' behaviours are as follows.

With regard to smallholder agriculture systems, due to reduction of land per capita both the land health feedback and the extensification feedback are dominant. By contrast, the strength of both the malnutrition and the investment feedbacks are re-enforced by the level of soil nutrient depletion factor. Concerning smallholder livestock keeping systems, both the rangeland health and the animal health feedbacks are made dominant because of the increased level of livestock keeper's mobility restriction. On the other hand, the relative strength of both the investment and malnutrition feedbacks is re-enforced by a depreciation of livestock health and productivity because of localised rangeland degradation factor. In addition, for both systems, the relative strength of the education feedback is re-enforced by both the investment and the infrastructure feedbacks due to a sharp decrease in cash income generation.

On the other hand, the feedbacks associated with both smallholder livestock keeping and agriculture systems differ significantly as to their respective interval of time over which they manifest their full pattern of behaviours (i.e. the concept of time horizon). Thus, for both systems, while the malnutrition, immobility, and informal credit feedbacks operate within a relatively short time-scale, the remainder of feedbacks have a long time span over which they operate. That is because it takes time to build stocks (e.g. skills, knowledge, soil nutrient content, capital, and livestock) because of flows that take time (Meadows 2008).

Q 2. What are key drivers of system change in these systems?

My results show that direct drivers, notably droughts, disease outbreaks, and animal raiding play a key role in regime shifts especially in livestock keeping systems, moving the systems from mobile to sedentary regimes owing to sudden and unexpected animal losses.

A set of indirect drivers constrain behaviours of both smallholder livestock keeping and agriculture systems through various actions. Both endogenous human population growth, property rights and land tenure arrangements contribute directly to soil nutrient depletion in smallholder agriculture systems, whereas cadastral policies together with property rights and land tenure arrangements contribute to livestock health and productivity decline in

smallholder livestock keeping systems.

In addition, for both systems economic drivers and political marginalisation of rural areas impede cash income generation, thereby refraining farmer and livestock keeper households from investing in soil fertility maintenance, veterinary medicines, water points and in education.

Q 3. What leverage points could enable breaking out of these poverty traps by weakening or changing feedbacks?

My work indicates that economic drivers as a whole constitute a high leverage point in that if appropriate adjustments are made, they can substantially influence the overall system behaviour. This is both by activating latent structural connections, such as formal insurance, financial credits contracts and labour markets, and by suppressing unfavourable terms of trade caused by high transaction costs (i.e. costs incurred by traders to reach smallholders) in the process of bargaining. As a result, the investment feedback could be weakened or reversed and thereby facilitate investments in factors of production, thereby reversing the dynamics of both the land health feedback and the animal health feedback.

Security of land ownership can increase incentives to invest for example in soil amendments and conservations measures controlling for other factors (e.g. accessibility to financial credits) which would contribute to reversing the dynamics of the land health feedback. By contrast, flexible property rights and land tenure arrangements would improve better management of water and pasture resources across the region. As a result, both rangeland health and animal health feedback dynamics would be reversed.

Investment in both education and human health services provision constitute additional points of high leverage in both systems. Both factors have the potential for increasing human capital (i.e. skills, knowhow) of rural household members, which, in its turn, could improve their productivity and therefore their income. As a result, poverty traps could be broken and by implication move the systems towards new stable states or regimes.

Lastly, good governance lends itself as a high leverage point in that it has the capacity of altering the action of many of indirect drivers thus reversing the dynamics of different feedbacks that maintain both systems in poverty traps.

4.2. Leverage points implications for system developments

The regime shift analysis I performed highlights the imperative of making structural changes in order to altering the dynamics of smallholder systems caught in poverty traps. My work indicates two fundamental findings.

On the one hand, the resilience provided to smallholder agrarian systems by the key variables (i.e. land/rangeland along with their inherent fertility and livestock holdings per capita) is in most cases in SSA exhausted. In fact, land fertility in most SSA countries show negative nutrient balances as a result of widespread soil nutrient depletion (Drechsel *et al.* 2001). The latter phenomenon has past the threshold point where soil fertility rehabilitation at best proved difficult or if envisaged as an option would be prohibitively expensive. As a result, food production and pasture growth are thus steadily jeopardised with time.

On the other hand, the amount of necessary asset transfers needed for change is limited. The number of landless and stockless in rural areas in SSA is increasingly great due to both human population pressure on the finite and already degraded available lands and to loss of livestock following frequent shocks of different kinds.

In the light of aforementioned realisations, smooth and continuous development of these systems whether through agricultural policies or agricultural improved technologies cannot be any longer expected. That is because the basic parameters of the systems, to be specific, soil fertility and livestock sizes have a limited range in which the systems can function without changing their system structures. Consequently, as the flexibility provided by soil fertility range is being exhausted as a result of soil nutrients depletion, changing system structure presents itself as the necessary step forward in order to ensure the survival of the systems. Thence, the best available option in many cases appears to be transformation.

Furthermore, my analysis revealed feedbacks and key drivers that maintain poverty traps and potential leverage points for breaking the traps. The question is how these leverage points operate as opposed to the challenges posed by key indirect drivers, given the current constraints and opportunities that smallholder agrarian systems exhibit in SSA.

Although the identified potential leverage points in section 4.1 present prospective solutions to altering the dynamics of the studied systems in the view of navigating them towards desirable basins of attraction, there seem to be some notable obstacles to be expected as to their actual materialisation.

The official development assistance (ODA) from the rich world in the form of capital transfers required to help households in SSA overcome their asset threshold, and thus achieve higher productivity by enabling them to increase their output, is still not provided. The call for 1 % of GNP in income transfer from rich countries by the UN Decade of Development since 1961 to combat extreme poverty seems not to be followed. As a result, the previously set 1 % of GNP not only got defined as 0,7 %, but most rich countries do not keep their promises with the USA for example giving only 0,25 % of its GNP in ODA (Sachs 2005).

My assessment showed widespread soil nutrient depletion in nearly all countries in SSA that show negative nutrient balances. Despite fertilisation intervention policies, that are recommended in current poverty reduction programs through resolving institutional and market failures, they do not generate expected results. The reason is that degraded soils limit the marginal productivity (i.e. incremental outputs) of fertilisers and as a result fertilisation becomes unprofitable at prevalent prices, suggesting that initial soil conditions will matter to the return on investments in fertiliser policies (Marenya and Barrett 2007).

De Soto (2000) advocates formalising of property rights over assets the poor use or possess in order to end their marginalisation and propel further capital production. Unfortunately, land tenure arrangements which are in effect in most SSA countries are fraught with various and complex rules that create inefficiencies. For the sake of argument, although current cadastral policies in the ASAL of east Africa comply with formalisation of property rights, they however are in opposition with the pillar of traditional livestock keeping, which is mobility of household livestock keepers.

Furthermore, my work showed that animal transfers constitute a leverage point that can prevent regime shifts from taking place through restocking of households who lost their animals in livestock systems. Yet, Lybbert *et al*. (2004) found that social insurance hardly provides a means for rapid restocking and that the scale of social insurance is very modest, signalling that households that consistently benefit from gifts and loans in the past are rationed out of animal transfers.

The constraints to breaking poverty traps mentioned above suggest increasing limitations of smallholder livestock keeping and agriculture systems to meet subsistence needs of the rural poor. Barrett et al. (2001) found that economic activity in SSA rural areas includes much more than mere livestock and agriculture production, just as rural incomes more generally reflects diversification beyond basic agricultural production. In addition, Bryceson (2002) found – from a study on de-agrarianization and rural employment undertaken in six African countries in SSA – that non-agricultural (non-farm) activities contributing a remarkable 60-80 % of rural household income, considerably higher than the usually quoted figure of about 40 %. This fact constitutes an important insight in that livelihoods and occupations of the many rural people increasingly are de-linked from both farming and livestock keeping.

Henceforth, rural spaces display currently features and points of broad direction of changes that are underway, which suggests the co-existence of two alternative attractors to which the systems are naturally attracted. There is one attractor whose structure revolves around livestock keeping and agriculture, and another one who is organised around off-farm

activities, which encompasses a big share of rural livelihoods and occupations as showed by the aforementioned statistics.

This reality calls for a new way of conceptualising development interventions different from the mainstream development ideology. The latter narrowly focuses on both land redistribution and policies of agricultural development viewed as the core of rural development, despite outstanding constraints and ongoing diversification of livelihoods and occupations in SSA, as I outlined earlier.

Therefore, I argue that time is ripe to start thinking in terms of opening up opportunities in SSA rural areas instead of trying to keep managing the systems at the margins through actions that only yield short-lived and piecemeal improvements. A two-track approach is worth undertaking and constitutes a necessary step forward in the transformation of smallholder livestock keeping and agriculture systems.

First, as given land has lost its strategic role for resource-poor households and the increasingly big share of poor landless, I argue that rural development would be propelled by other factors and capabilities. In fact, human capacity building through acquisition of new knowledge and skills can increase people's capacity to escape from farming towards activities that yield higher returns than farm investments, given the current meagre size and low quality of the asset base at their disposal. This is supported by Krishna (2006) who found that coming out of poverty is facilitated by education together with information about remunerative job opportunities.

Furthermore, my results show that improvement in both health status and physical stature could increase farmer and livestock keeper productivity. This is confirmed by Krishna (2006), who found that health care service provision could cushion rural poor households not only against earning capacity reduction caused by health shocks but also against expenditure burden that they cause.

Second, the relatively few households who possess enough quality and quantity assets base (i.e. land and livestock, human capital) ought to make a transition from being subsistence-oriented farmers to becoming market-oriented and commercially aware entrepreneurs. Such a transition process requires those farmers and livestock keepers to acquire a certain level of farming husbandry together with managerial skills to meet the demands of the market.

Moreover, there is a need for a qualitative shift in the narrow rural/land/farming paradigm, which dominates much of current development policy in SSA countries if the transformation process is to materialise. Policies ought to aim at facilitating and assisting the process of transformation of farmers into non-farmers, rather than at consolidating livelihoods of

smallholders into farming or livestock keeping, which incidentally is a mere poverty perpetuating and stagnation.

Therefore, good governance plays a key role in managing social-economic and ecological systems. A strong and enabling institutional framework and appropriate policies are prerequisites to any successful production system (Barrett *et al.* 2006). Smallholder livestock keeping and agriculture systems are no exception. Furthermore, taking into account that rural areas in most SSA countries are subject to the political, social marginalisation, and inequalities, there is a need for instituting an enabling institutional framework conducive to the much-needed transition.

Finally, my findings show that there is a need for a proper alignment of development policies given the multiplicity of key factors behind persistent poverty. This requires one to develop synergies among intervention actions at different scales of social organisation. Barrett and Swallow (2006) who recommend paying attention to coordination of different institutions at different scales of social organisation if poverty traps are to be broken support that.

4.3. Reflections on the approach

The regime shifts framework requires a highly interdisciplinary knowledge base in addition to systems thinking and modelling, necessary to derive leverage points and informed management interventions schemes, which makes the regime shift framework a knowledge-demanding undertaking.

Moreover, the framework is highly dependent on a detailed understanding of linkages between relevant variables of both human and natural systems in the SSA. Yet, this understanding is not empirically well developed in the literature. Much of what is actually known stems from case studies or is simply suggested theoretically. This consequently affects the outcome of the assessment performed using the regime shifts framework.

Therefore, there is a need for bridging this knowledge gap if the comparative advantage of the regime shift approach is to be realised. Furthermore, there is as well a need for improving the identification of management interventions, as it currently simply identifies them without any prioritisation. Prioritisation is a real management issue that needs to be considered to save time and limited financial resources. This calls for enhancing scientific understanding through empirical research on the interlinked dynamics of human well-being and natural renewable resources. Models underpinned by rigorous empirical evidence of these dynamics can help managers and policy makers to assess the relative merits of alternative courses of action.

Notwithstanding shortcomings, the regime shifts framework helped me to gain insights into

system behaviours, i.e. of its particular configuration of system elements and their interconnections. These insights not only critically allowed me to realise that the resilience provided by basic parameter ranges of the studied systems is exhausted and that system developments could not go on without changing system structures, but also made me see the paramount significance of changing their structures if the survival or sustainable livelihoods of the studied systems are to be improved. Therefore, I recommend the use of regime shifts framework for analysing dynamic and complex processes if sound natural resource management is to be the goal of any society.

5. CONCLUSIONS

Development policies in the SSA are dominated by economic understanding, which stems from participatory poverty assessments performed at specific moments in time. However, poverty is inherently dynamic phenomenon, which calls for an assessment approach that explicitly includes dynamics. The regime shift framework takes account of social and natural interactions or processes from which poverty traps emerge. With the help of both systems thinking and modelling, I argue that an alternative course of action has to be taken to deal with persistent poverty in rural communities in SSA.

The main result of this analysis suggests that a transformation of smallholder livestock keeping and agriculture systems should be envisaged if the well-being of the majority of rural people is to be improved given that land – which used to be a strategic asset – has lost its strategic role for these farm households. Investment in human capital presents a large advantage for achieving the transitioning process towards sustainable livelihoods in the rural areas of the SSA. Appropriate policies ought to be aimed at both facilitating and assisting the process of transforming farmers into non-farmers and livestock keepers into non-livestock keepers. Provision of new skills through training and education as well as preventive and curative health care carry good prospects. Equally important, policies should help relatively few farmers and livestock keepers who remain on the land/range to make a transition from being subsistence-oriented farmers, that is, production units that produce largely to meet basic needs in the current systems, to becoming market-oriented and commercially aware entrepreneurs. Therefore, I argue that structural change of smallholder agrarian systems presents itself as the only way forward if poverty traps are to be dealt seriously and thus envisage sustainable livelihoods in the rural communities of the SSA.

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