

14th ICCRTS

“C2 and Agility”

Assessing Resilience in Complex Adaptive Societal Systems

Topics 6, 8

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Abstract

In this exploratory study, we adopted an existing analytical framework, based on the assessment of resilience in complex adaptive systems. This approach has been successfully applied, for example in the management of complex social-ecological systems. It emphasizes the apparent self-organizational and transitional character of complex adaptive systems, and denotes an intervention strategy based on resilience attributes, like (response) diversity, resistance and adaptability. As an illustrative case we aim to address the dynamics of today's Afghan society for the resilience analysis in an operational context. This Afghan "human terrain" possesses all aspects of a complex (adaptive) system. In our analysis, the resilience attributes are regarded both spatially and temporally, at different scales, and within (and between) relevant domains. Moreover, it explicitly incorporates the role of each stakeholder. As part of the analysis a simple agent based model of the Afghan opium economy has been developed. We believe that, eventually, this combination of assessing resilience of the human terrain, together with a set of qualitative and quantitative tools, can contribute to more effective (military and humanitarian) operations based on improved understanding and guidance in implementing an overall intervention strategy.

Introduction

The exploration presented in this paper is based upon the notion that complex system theory, its consequences and applications are already recognized in many non-military domains. Examples are the social, economic and ecological domains which provide a large body of knowledge and experience in how to understand and deal with complexity when intervening within complex and evolving system. Aim of our exploration has been to search for a potentially useful approach that enables a comprehensive and methodological approach to the intervention in complex adaptive systems. In particular we studied an assessment methodology based upon the notion of resilience in social-ecological systems [14, 15, 16, 28]. This notion recognizes the need for understanding a system from a variety of stakeholder perspectives and states that change within systems should be viewed from a complexity point of view. Such a view incorporates cross-scale and cross-domain relations, and stresses the importance of understanding the non-linearity within these systems. As a result, successful intervention concentrates upon those factors within the system that actually drive the system. Typically these factors are associated with self-organizing and adaptive mechanisms and therefore, interventions are rather aimed at inducing then enforcing change and transition.

In the next few paragraphs we will provide an overview of the proposed approach applied in a more military context. First we will highlight the overall assessment procedure and second, we will illustrate this procedure by a military relevant case inspired by the current challenges in Afghanistan. Finally we will discuss the role of tooling, in particular the role of models and simulation within the context of this assessment.

Introduction Resilience Assessment Framework

Resilience¹ is a central theme within the assessment and refers to ability of these systems to absorb change and still persist. For example the military is confronted with the aspect of resilience when trying to decrease the power of opposing forcers, or when aiming at reconstruction or the provision of humanitarian aid. Understanding the associated factors and processes of why certain system configurations² will persist while others vanish may provide insight in how to alter these configurations. Taking a resilience perspective may aid in the recognition of alternative configurations and the identification of the means how to induce transitions between them. The breakdown of the resilience in systems with undesired configurations, or the strengthening of resilience in system with a desired configuration is at the core of a resilience perspective.

The considered framework for resilience assessment is depicted in Figure 1 (from [28]). The whole assessment consists of four phases, or steps. Each step involves exhaustive stakeholder³ participation. Note stakeholders are broadly defined and involve all actors and parties that have an interest within the system. It's essential and inevitable to reconsider the system description during the whole process. Newly gained information or new insights may require further necessary examination of all assessment aspects. Therefore, after each step the system description is evaluated and revised.

¹ Within this document resilience defined as the ability of a system to stay within or maintain it's basin of attraction despite the disturbances acting on it (for example how well does a rural community cope with extreme droughts). Both external drivers (for example climate) and internal processes (for example political regime changes) can lead to changes of the resilience of a system.

² Configuration refers to a collection of states of a system who's dynamics stay's within the bounds a certain range of criteria. Note that this does not imply stability as known from a mathematical point of view (mathematically a configuration refers to a particular attractor which can have many states).

³ Stakeholders will involve a variety of parties and actors. From a military perspective this implies considering all relevant non-military actors and parties as a stakeholder.

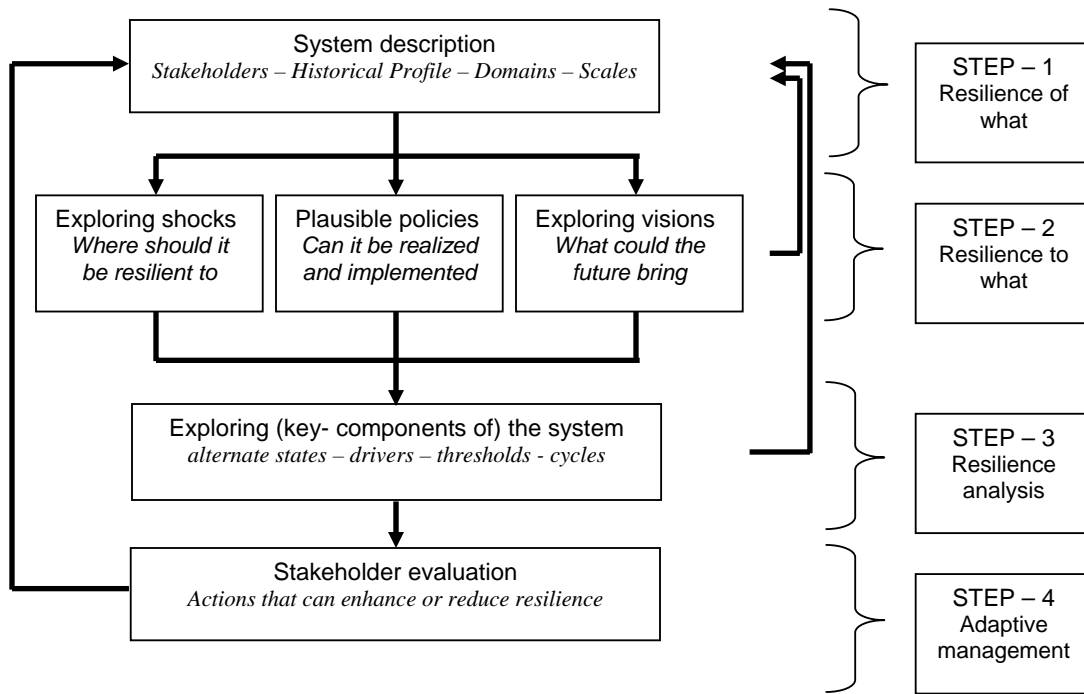


Figure 1 Resilience Framework

Resilience of what

The first step is meant to bound, define and understand the system under investigation. It involves stakeholder participation to understand their concerns, issues, and goals. It should be determined in which domain, and on which scale⁴ each of these (inter-related/ intra-related) issues occur. These issues should be regarded in a broader perspective in two ways. First, a certain issue in a certain domain on a certain scale is probably related to other issues in others domain on other scales. In order to manage these issues, the critical economic, social, and political processes that operate above and below the focal system should be identified. Second, the criticality, the relatedness, and the influence of issues can change over time. A historical profile of the system should give an overview of these (types of) changes, i.e., system dynamics. At the end of this step an initial and rough description of the system will be available. Refinement of this description will take place by revisiting this step and reconsidering the initial findings throughout the remaining assessment.

Resilience to what

Based upon the initial findings in the first step of the assessment, the next step is to consider to what the system will be resilient to and tries to gain insight into how interventions may alter

⁴ Scale, and it's components like resolution and extent, is an important aspect in the study of complex (adaptive) systems. Scale is typically observer defined, as we denote with the recognition of a *focal scale*. However, since many processes within complex systems take place over a range of scales, considering other scales then just a focal scale is required.

the dynamics and thereby future regimes/configurations of the system. This implies the recognition of disturbances, issues that may fundamentally alter the nature (structure and/or dynamics) of the system, and the identification of possible configurations (alternative states⁵) the system can be in. Disturbances can be identified by studying and assessing change of historical events that altered the system's configuration. Next, scenarios can be used to identify future (desired) configurations that eventually combine into a first broad overview of and insight in the factors affecting the systems sensitivity and possible system responses. Based upon these insights, plausible paths might be identified along which the system could move from one configuration to another.

Resilience analysis

The third step is meant to combine the outcomes of the previous steps. Aspects which govern the dynamics of the issues judged important by stakeholders should be identified. Determining these aspects is required in order to understand how interventions may alter the systems' dynamics, and possibly alter (future) system states. Important aspects include: drivers, disturbances, thresholds, alternative states, state transitions, and adaptive cycles. Drivers may keep the system in its current state, while disturbances may push the system into another state, establishing a system transition. Drivers and disturbances may function according to threshold functions: once a threshold has been crossed, the system state may be altered. Therefore, it is important to identify thresholds, their nature, and what determines their positions along these drivers and disturbances. Thresholds may be linear, resulting in reversible changes, and non-linear, possibly exhibiting hysteretic and irreversible changes. Moreover, crossing thresholds can result in a cascade of effects over time, scales, or domains on a range of issues. The last aspect is the acknowledgement of adaptive cycles. The adaptive cycle describes four phases of change (growth, conservation, release, and reorganization) that are characteristic of many systems. Determining these phases is important because different management and policy interventions are appropriate in different phases [28]. This step ends with an overview of potential drivers, possible thresholds, possible cascades over time, scales, and domains, possible state-transitions, and a description of issues related to the adaptive cycle.

Adaptive management

The last step of the assessment is to assess possible options and strategies for intervention. Within this part of the assessment actions are identified that would induce the movement of the systems along a plausible, desired path. Typically these actions are adaptive in their nature, allowing integration of new insights into the overall understanding of what the actual system is about. Managing resilience requires adaptability – the ability to monitor, assess, respond, recover and renew following known and unknown disturbances and other change. An adaptable system is able to maintain or manage resilience. Sometimes transformation or fundamental change of the system is required. Such a transformation may involve the breakdown of resilience for undesired configurations, while trying to increase prerequisites for the resilience of desired configurations.

⁵ The term alternative state refers to the existence of multiple states for a given set of conditions.

Resilience in a military context: Afghan case

To explore the applicability of the proposed assessment we've selected Afghanistan as a test case. Rather than an in-depth assessment, which would heavily rely on stake-holder input, our assessment is mainly based upon literature. Its primary objective has been to challenge the proposed resilience assessment methodology from a military perspective. In the next paragraphs a summary of this assessment is provided, highlighting some of the most relevant findings. It should be noted that the results of this assessment are not meant to provide solutions or answers to current mission issues.

Main issues and bounding the system

The first step in the assessment is to describe and demarcate the boundaries of the system under consideration. For the Afghan casus the opium economy in relation to insurgent persistence has been selected as the major issues. These two tightly coupled aspects are strongly related with extreme poverty and conflict dominated Afghan landscape. Choosing an appropriate geographical scale turned out to be challenging. Initially, our efforts have been restricted to the Tarin Kowt and Chora district, focusing on the Baluchi and Chora valleys. Soon, it turned out that both the opium economy and the insurgent persistence in this small region is difficult to interpret without considering its larger geographical, social and temporal context.

Table 1 Enumerated are the identified levels at spatial scale, social scale and temporal scale. Note that identifying and defining scales turned out to be challenging and deserves more attention than given within this exploratory study.

	level below	focal scale	level above
social	household	community	tribal
spatial	farm	village	regional
temporal	months	seasonal	years

The opium economy is a world-wide phenomenon. Since most of the demand is outside the producing area there are strong international influences. Prices for opium are largely determined by world markets and international criminal organizations play an important role in the supplies. At the district level we typically deal with the supply networks connecting workers, farmers and traders. The level just below the focal scale we look at farms at which poppy will be produced, villages where shops and markets are enabling the trade of farming products and transportation roads connection these local production and trading units with the large scale markets of the wholesalers and exporters. Warlords and many Afghan powerbrokers in general, play a crucial role in the development and persistence of the opium economy [9, 19].

Due to their financial dependencies on poppy trade many of these powerbrokers have a profound effect on the creation and maintenance of an environment in which these illegal activities can flourish. Their involvement creates a reinforcing effect, in the meanwhile undermining governmental influence. Figure 2 shows the inherent relations between actors within the opium supply chain and with powerbrokers. In summary, Figure 2 shows that the opium economy has positive effect on the power base of the warlords by providing them with

financial means (paid commissions) and a labor force. The opium economy in turn receives protection and takes advantage of existing, warlord controlled, supply lines. By creating an unsecure environment warlords undermine the power of a central authority or may even actively rebel against it. Combined with an increasing corruption the weakening of the government affects the overall security, reinforcing the opium economy.

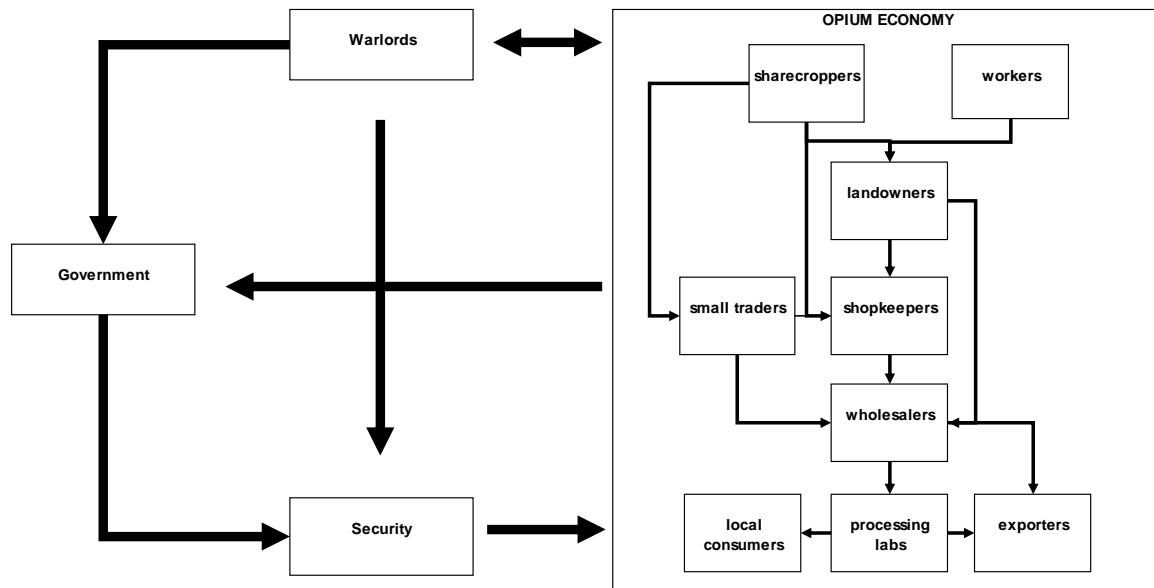


Figure 2 A simplified diagram showing relations within the opium supply chain and with powerbrokers, like warlords.

Historical profile and disturbances

Looking at Afghanistan from a resilience perspective shows an exhausted and severely damaged country. Decades of war and severe climatically disasters devastated much of the socioeconomic structures in Afghanistan. During these periods of sustained pressure much the country's infrastructure was destroyed and its social capital like educational systems diminished. The majority of the Afghan population is living in extreme poverty, lacking most of the critical needs like food, and clothing, housing and medical care. Due to the prolonged periods of war and conflict most of the country's monetary system has collapsed, leading to a role of opium as the currency for exchange and the only form of saving [8, 24]. With the rise of the Taliban, which imposed a fundamentalist regime on the country, the remnants of financial sector disappeared almost entirely, and the provision of social services deteriorated – including health services and education. Nonetheless, the overall economic situation at least stopped deteriorating in the first years of the Taliban. Much of this progress, however, disappeared following severe droughts which affected most parts of the country [3, 10, 26]. The dramatic drop in food supply, a consequence of Taliban international policy - created a severe food emergency, making several million people dependent on international food aid in 2001. Thus, as of late 2001 all available social and economic indicators pointed to Afghanistan being a country on the verge of complete collapse. Within this context the international community decided to intervene within Afghanistan, facing the challenge of rebuilding a collapsed state.

Vision and future pathways

Managing resilience involves considering the future. Scenarios, descriptions of possible future developments, help to understand aspects of system dynamics. Comparison of a few scenarios reveals drivers of change, major uncertainties, options for action, and plausible outcomes.

In this study we defined several scenarios. From a legal government point of view, scenarios with an undesired outcome focused on a future with prolonged opium dominated economy, either due to the exit of aid [partially adopted from 18, 25], debt lock [29], or increased insurgency targeting ANA and ANP [21, 25, 27]. Scenarios with a desired outcome focused on a future with growing support for a legal government, either due to a ban of opium [12, 17], or successful alternatives for opium, like poppy for medicine [20] and saffron [4, 5].

Analysis

States and transitions

Using the main issues, boundaries, disturbances and envisioned pathways we defined the poppy and insurgent persistence issue as a simplified system of just two states. We recognize that many other states could have been identified but focus on methodology rather than completeness. Identified configurations are based upon a number of literature sources including those dealing with the historical chain of events in Afghanistan and various failed state literature. Based upon these sources we recognized two plausible and alternative configurations. The first configuration characterizes the current situation of Taliban dominated Afghanistan just prior to and early on after UN intervention. This configuration coincides with a so-called failed or failing state. Characteristics of the configuration are the dominance of the warlords (by ruling of the Taliban) and flourishing war economy based upon opium. An alternative configuration is the opposite of this situation characterized by a legal and legitimate government with a legal economy.

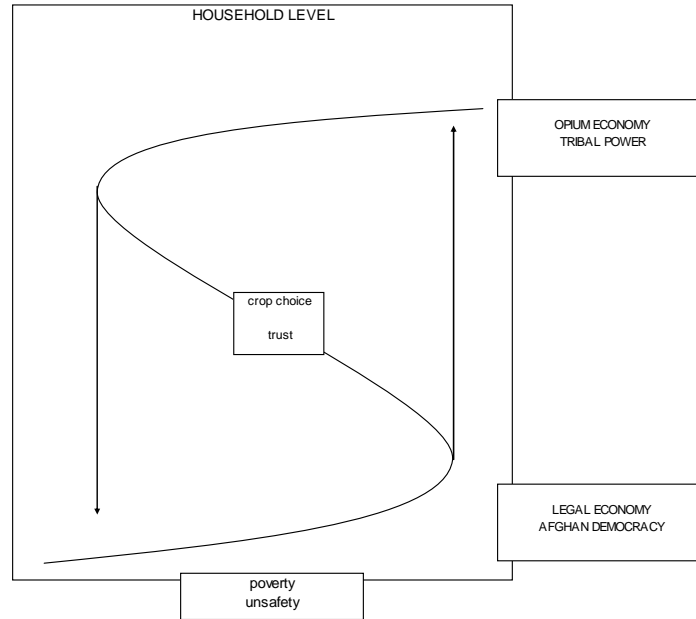


Figure 3 Thresholds may take many forms. Understanding their existence and their dynamics are essential in understanding transitional behaviors in complex systems. This figure shows a hypothesized hysteresis threshold effect between two configurations.

Hysteresis is a particular illustration of path dependency, in a sense that the path into a certain configuration is not necessarily the same as the path back into this configuration. For this particular example, such an effect would imply that the critical level of income that causes Afghan farmers to choose for poppy cultivation is not the same as the level that make Afghan farmers to move back into legal products.

From an international perspective the Taliban dominated situation is unacceptable. The UN intervention is actually for a transition of this situation into the much more desirable situation with a legal government and economy [22]. We explicitly consider this change as a transition since we think such a transformation will deal with many threshold bounded aspects (like public support, opinion, cultural change, economy changes).

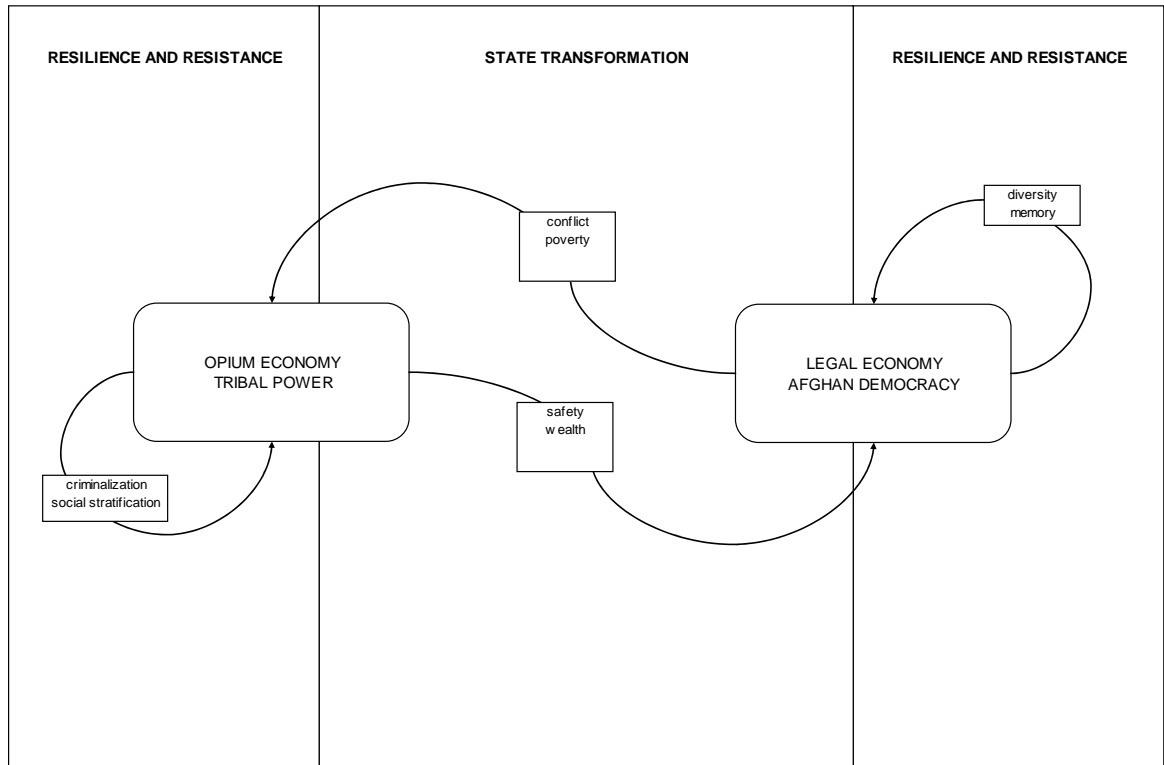


Figure 4 A state – transition diagram with a legal economy and an opium based economy as states, and conflict and poverty are identified thresholds to move from one state to the other (transition)

For reasons of clarity, we focus on just two aspects of inducing a transition: poverty thresholds and conflict related thresholds. From literature it seems these two thresholds come hand in hand, in a sense that large scale and long lasting conflicts diminish livelihoods by destroying infrastructures, services and trust [1, 2, 3, 12, 18, 19]. Although Afghans have dealt with many of these stresses, eventually their abilities to adapt and withstand these shocks and disturbances have been exhausted making a transformation into an undesired regime inevitable. Due to failing governments, tribal powers are dominant and eventually many Afghans become involved into the opium economy.

Transitions between configurations are assumed to be governed by the crossing of a set of thresholds. In Figure 4, an illustrative example is visualized in which both conflict and poverty are the identified thresholds. On the one hand, crossing these thresholds and thereby moving the system into an alternative configuration can be seen as a transformative process. On the other hand, the resilience and resistance of the system in a particular state will actually prevent such transitions and try to keep the system in place. Examples of such influences include social stratification and criminalization associated with the opium and warlord dominated system. These influences and economy factors like lack of alternatives, enduring poverty and absence of formal credit systems prohibit many Afghans to escape the current situation, i.e. they are locked in this situation.

Thresholds

Managing resilience requires identifying and managing the critical thresholds that separate desirable states from undesirable states. For the Afghan case we identified a number of potential thresholds. A wealth threshold is associated with the choice to become involved within the opium trade. For many Afghans, poverty is a driving motivation to get involved with the production and distribution of opium [23]. This opium-wealth threshold is closely connected to a power–safety threshold in which public opinion and supports for warlords will have a reinforcing effect on these previous thresholds. Figure 5 is a diagram illustration, showing how thresholds at different scales and domains can be connected. Such connectivity may lead to cascades and potentially feedbacks throughout the system, causing large regime shifts. Understanding such connectivity between scales and domains may offer useful insights in the overall dynamics of the systems. Moreover it may give insight into how small changes may induce large scale effects that move the system into new configurations.

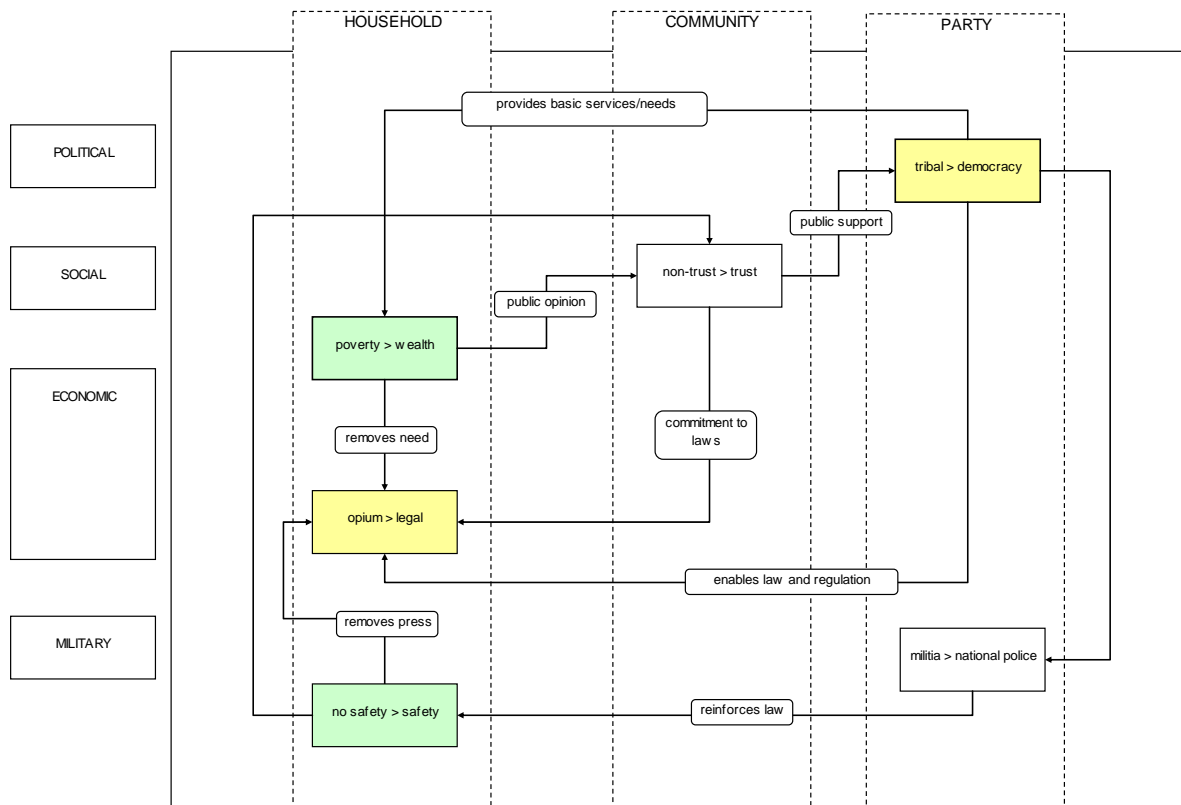


Figure 5 Thresholds and Cross scale interactions.

The wealth thresholds act on the household level, in a sense that at a particular level of income households can not sustain themselves any longer. Since many Afghans will hold the government responsible for this economic decline, such a decline may severely affect trust in this government and thereby public opinion and support for them. Indicators of such a decline in public support are the dominance of tribal power structures, including those involving warlords, and in a little or no commitment to governmental laws and rules. Eventually the

decline in wealth and trust, the shrinking power of the government in favor of local powerbrokers, and the decrease in overall safety due to these powerbrokers, the likelihood of households being opium related becomes more likely.

Adaptive Cycles

The last important aspect is to view the main issues stated in terms of the adaptive cycle. In our study, we identified political cycles, and cycles related to opium and insurgency. In Figure 6 the sequence of ruling parties in Afghanistan for the past 60 years has been visualized. The rise (*growth*), rule (*consolidation*), and fall (*release*) of each regime are clearly visible. The settings or forces which enabled each regime to become the ruling party (*reorganization*) are less visible. The Soviets (USSR) invaded to bolster the faltering communist regime of the republic of Afghanistan. The resistance against the Soviet communist evolved into so called Mujahedeen that led to the withdrawal of Soviet troops. In the power vacuum left, warlords seized the opportunity to fight over the future of Afghanistan. After years of drought, famine, and war, the Taliban, an Islamic militia, promised peace, and got the support of the Afghan population. The conflicts between the Taliban and international parties led to US and UN intervention. The UN attempts to support and establish an Afghan legal government. So, the political cycle is not just one cycle, and is not solely based on political aspects. Aspects from other domains, like droughts, religious principles, and war, have their impact on the political domain. These aspects from other domains serve as triggers for a demand of change of politics.

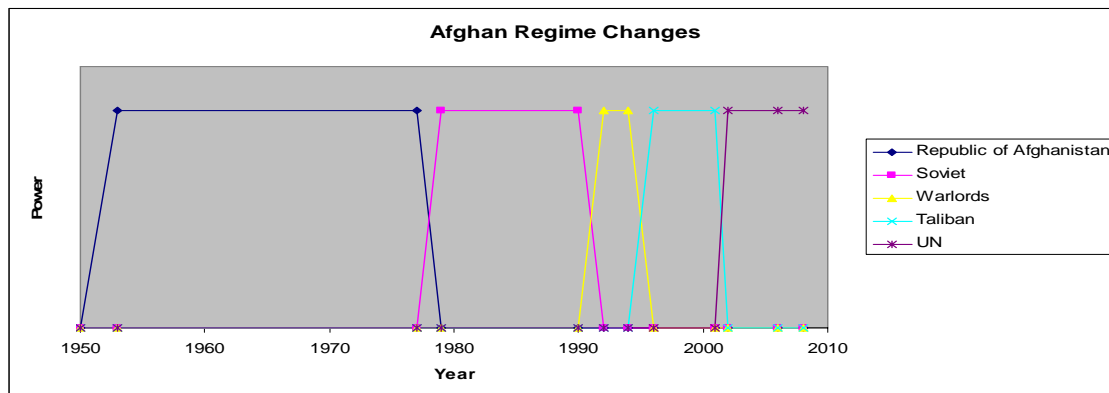


Figure 6 Afghan Regime Changes, Political cycles

Two other cycles can be identified, both related to the cultivation and production of opium. The first cycle has a seasonal nature and relates to the farming of opium. During a year, farmers choose their crops (*reorganization*), allow it to grow by creating correct circumstances like irrigation and fertilizers (*growth* and *consolidation*), and harvest them afterwards (*release*). Each phase demands different workloads, and therefore affects farmers' behavior. This behavior has become eminent for example by so-called spring offensive of the Taliban in which insurgent activity seemed to be aligned with the poppy growing phase [11, 13].

The second cycle is a potential cycle and is hypothesized from the overall cultivation of opium during the past 20 years, depicted in Figure 7 (from [24]). Whether this overall cultivation functions as cycle is yet uncertain. If it does, it's currently in a growing or consolidation phase.

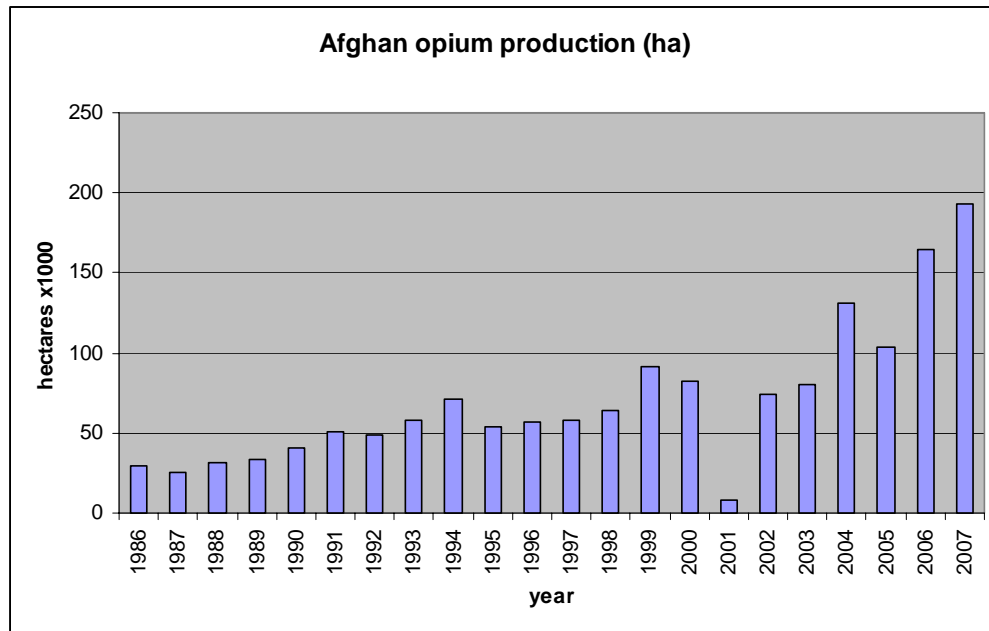


Figure 7 Opium production in Afghanistan

Adaptive management

From an intervention point of view Afghanistan is a most challenging subject. In a typical assessment the last step would involve the identification of possible options and paths for intervention. Due to the preliminary character of our assessment and the challenging Afghan situation this is not possible at this stage. However there are number of general findings that are worth exploring in a future study. Intervening in a complex and changing system require a high level of adaptability of the involved actors. Key aspects of this adaptability would imply the search for drivers of change within the Afghan communities and the ability to identify windows of opportunities by careful observation of the possible (adaptive) cycles at hand. At the civilian level, alternative livelihoods should be fostered, enabling people to escape the poverty lock.

Role of modeling and simulation

A next step in our exploration of the assessment methodology has been to study the role of models and simulations. Often, (computer and mathematical) models are associated with extrapolation and predictive tools that enable us to generate insights in what might happen. And although such a role of models would be extremely valuable from a mission perspective, we rather look at models as tools in a sense making process. Typically, models (and simulations) may help to visualize aspects of complex dynamical systems or can be used to study (assumed) relations and processes in much more detail. In such a way models and

simulations may support the process of gaining understanding of real complex systems by guiding and shaping the way we look and think about these systems. Especially for the non-kinetic aspects of modern mission areas, models and simulations can be valuable tool for enhancing our understanding. In particular, the lack of data or sometimes even the lack of knowledge may hamper the understanding of these systems. Models and simulations, although primarily based upon expert considerations and assumptions, can support a sense making process. For example, using models to formalize our considerations may actually help to make assumptions explicit thereby highlighting consequences or even mismatches and gaps in our presumed knowledge.

To explore the role of models and simulations in the context of the proposed resilience perspective we developed a simple model, bearing some of the aspects generated throughout this assessment. And although the assessment does not favor any modeling formalism in particular, we choose an agent oriented approach. Major arguments for this choice are, besides the ease to deal with both spatial and networked aspects, the widespread use of these agent oriented models in the study of adaptive and self-organizing behaviors, which are key aspects of resilience in complex adaptive systems.

Our model has been adopted from an agent based model of civil violence as proposed by [6, 7]. Although this model has not been validated with real data, it does capture a number of typical aspects associated with human societies like rebellion. In their model, rebellion of civilians against a central authority is assumed to be affected by a combination of both perceived hardship of the population and legitimacy of the central authority. To align this model with our assessment efforts, we extended the model by introducing an opposing (anti-governmental) force trying to gain control over territory by fighting the governmental forces. The latter is, for the sake of simplicity, just represented by a police like force that tries to deflect rebellious civilians, criminals and insurgents. Next we defined both hardship and legitimacy as endogenous (in the original model these parameters has been defined exogenous). This has been realized by introducing a simple resource-gathering process [7]. As a result, hardship could then be defined as affected by the levels of wealth in individual agents. Next, the distribution of wealth could be employed as a measure of inequality, affecting the legitimacy for the central authority in individual agents. Besides this economic measure for legitimacy, crime has been introduced to allow for a measure of the sense of security perceived by agents.

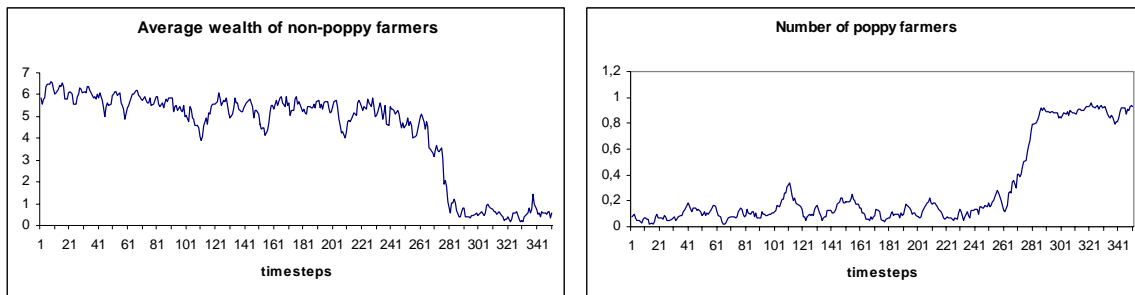


Figure 8 A stylized examples of a simulation result, illustrating the switch from legal production to opium production. This switch is induced by a sustained drop in the production rate of the resources. Peer pressure effects, agent tend to follow their neighbors, reinforces this switch over the agent population leading to a swift and abrupt change.

In general terms, the behavior of individual agents can be described as follows. Civilian, non-rebellious agents collect and consume resources. The availability of these resources is spatial distributed and is constrained by both demand and production levels. Depending on amounts produced and received prices (provided by traders which both set prices and define levels of demand) agents may gain wealth. A substantial drop in their levels of wealth will affect perceived hardship (Figure 8). High levels of perceived hardship, combined with a drop in legitimacy may result in rebellion, made explicit by the choice for the collection of illegal resources and thereby support for opposing forces. Two types of resources are defined, one legal and one illegal. Agents collecting illegal resources will indirectly support opposing forces by assuming that commission has to be paid to opposing forces for protection of the illegal production processes.

This model enables us to visualize the dynamics of the proposed scenarios. For example, by applying sustained pressure onto the resource availability a cascade of effects can be generated that follows transition towards an opium dominate configuration. We expect that such a visualization of the dynamics may aid in the overall assessment, especially during discussions with stakeholders. During our exploration several aspects of the role of modeling and simulation appear. First of all is the lack of validated models in literature, in contrast most models are of an abstract and conceptual level, rather used to express expert considerations than explaining real life issues. However, the dynamics of complex and adaptive systems is difficult to imagine or visualize without the use of mathematical and computer tools. Especially when dealing with the internal feed back processes in these systems, models will be a valuable tool for generating insight. Another finding has been that the use of models may actually enforce us to be explicit about the underlying assumptions. For example assuming the existence of certain thresholds or a particular behavior of a system around such a threshold behaviors (i.e. gradual or hysteric) will greatly affect overall dynamics. By an explicit (mathematical) expression of these aspects it will be easier to understand the consequences of such assumptions. Finally, by developing models one will gain insight in the relative importance of the various factors of a system. In such a way, modeling may help by reducing the number of factors that need to be considered.

Discussion

Aim of this study has been to assess the applicability of a methodology for assessing resilience in complex adaptive systems. Although an in-depth assessment should imply the involvement of stakeholders, our initial findings suggest that a resilience perspective is a potential useful approach. Such a perspective stresses the importance of utilizing a systems capacity to withstand shocks and self-organize into (desired) configurations. Enhancing our understanding of these system properties may help to find means either to breakdown the resilience of systems with undesired characteristics (like the persistence of insurgency) or foster and promote desired characteristics by creating and managing the prerequisites for the resilience (like the possibility to prevent and escape poverty, ability to withstand economic stresses, etcetera).

Even though the original work has been developed for the study and management of social-ecological systems our exploration suggests that this approach has value in a military context. This value becomes even more profound when considering the increasing orientation towards humanitarian and reconstruction efforts during today's military missions. A particular interesting aspect of this assessment is the focus on thresholds and associated transitions of systems between configurations (or states). Such a view on moving a system into a desired configuration by utilizing as much as systems own properties and processes is an essential aspect of effective interventions with limited capacity and/or duration.

The role of tools and techniques like modeling and simulation can be part of an assessment. To evaluate the role of models and gain hand-on experience a simple agent model has been developed and its role within the overall assessment has been evaluated. Main findings suggest that utilizing these models enforce one to become explicit about assumptions and helps in understanding the relative importance of certain system characteristics like relations between entities or the consequences of assumed thresholds.

As a next step of this research we will conduct an assessment with real stakeholders for cases in Sudan and Burundi and meanwhile evaluated the applicability and gain of this methodology.

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