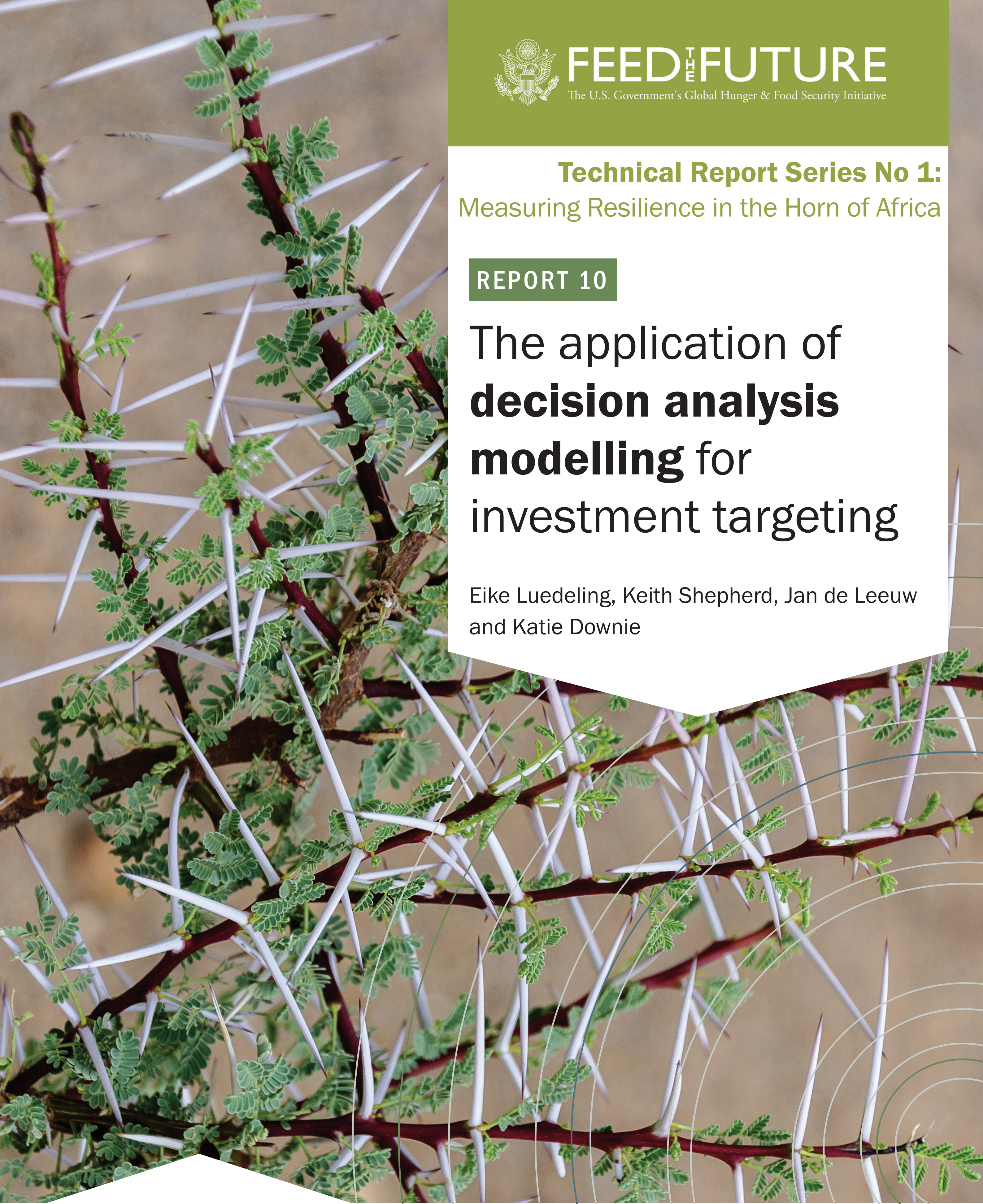

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Technical Report Series No 1:
Measuring Resilience in the Horn of Africa

REPORT 10

The application of **decision analysis modelling** for investment targeting

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Building Resilience in the Horn of Africa
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1 Introduction

A CGIAR review of global monitoring systems in agro ecosystems and livelihoods concluded that there is little evidence that initiatives have impacted on decision making, and proposed a decision analytical framework for the design of new initiatives[1]. In partnership with Hubbard Decision Research, the CGIAR has proposed an intervention decision modelling framework (IDM) for estimating the impact of interventions, determining how to measure and monitor development outcomes, and showing the value of research[2]. The framework applied the Applied Information Economics (AIE) approach developed by Hubbard Decision Research[3]. The IDM is currently being applied to a sample of six cases across the strategic research portfolios of the CGIAR Program on Water, Land and Ecosystems (http://wle.cgiar.org/), including sustainable intensification or rain fed agriculture including pastoralist systems. The Horn of Africa project will be integrated into this framework, with a focus on measurement of resilience and modelling of portfolios of investment options. Key elements of the approach are summarized below:

- **Clarify the decisions that measurements will support.** The need for data should be determined by the specific decision these data will inform
- **Model the current state of uncertainty.** The consequences of the uncertainty in variables are assessed using "Monte Carlo" simulation and a special method for training experts to assess probabilities. This initial model is effectively a snapshot of the current state of uncertainty about a problem before additional measurements are made.
- **Determine the "information value of variables and the identification of high value variables in a decision".** With AIE, every variable in a model will have an "information value" that allows identification of high value variables in a decision. This approach targets only the variables in a decision that are the most likely to significantly reduce overall uncertainty in the decision.
- **Measure what matters.** Once the high-value measurements are identified, a variety of empirical methods can be used.
- **Make better decisions.** The output of the Monte Carlo model, updated with targeted measurements, is compared to the risk/return preferences of the organization or decision maker.

The modelling approach will provide an empirical rationale for assessing potential impacts of investment by sector on enhancing resilience. This rationale is necessary to underpin decision-making processes for sectoral intervention prioritization in investment planning documents such as the IGAD Member States' Country Programme Papers and could assist considerably in aligning other investment initiatives (World Bank, IMF, AfDB, etc) in the region in a common Monitoring and Evaluation framework, including common impact variables.

[1] Shepherd, K.D., Farrow, A., Ringler C., Gassner A., Jarvis A., 2013. *Review of the Evidence on Indicators, Metrics and Monitoring Systems.* Commissioned by the UK Department for International Development (DFID). Nairobi: World Agroforestry Centre. http://r4d.dfid.gov.uk/output/192446/default.aspx

[2] Shepherd K.D. and Hubbard D.W. 2012. *The Need for an Intrenvention Decision Model.* Concept Note. World Agorofrestry Centre, Nairobi

[3] Hubbard DW., 2010. *How to measure anything: finding the value of "intangibles" in business.* 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

The use of **decision analysis tools** for measuring resilience in the Horn of Africa

2

In June of 2013, the Technical Consortium for Building Resilience in the Horn of Africa (TC) hosted a three-day workshop to convene key experts. The purpose of this meeting was to further examine the potential for application of decision analysis tools in measuring impact of investment, prioritization of investment and assessment of return on investment with respect to resilience.

A pilot decision model (preferably for a portfolio of investment alternatives) was developed, with the aim of documenting the model and approach and providing a report by December 2013.

The meeting focused on the following key activities:

1.1. Exposing the group to the Applied Information Economics Methods (0.5 day instruction).

1.2. Clarifying the decision problems to be addressed drawing on country plans. Chose one pilot decision problem for developing and demonstrating the overall approach (1 day).

1.3. Defining dimensions of resilience in relation to the decision problems and identifying variables to measure them (1 day)

1.4. Defining important variables for the models.

2. Identifying a core group (including relevant stakeholders) who will contribute to further model development and provision of estimates.

3. Providing calibration training to the modeling group and anyone who will be providing estimates.

4. Developing a pilot decision model (preferably for a portfolio of investment alternatives) to further develop the approach. Document the model and approach into a report.

Following the workshop, an exercise was undertaken to employ the decision analysis modeling methodology presented in the meeting in prioritization of decisions for investments or projects in the Horn of Africa. This approach is described in the following terms of reference.

3

Terms of reference: Assessing resilience in the Horn of Africa – an applied information economics approach

EIKE LUEDELING, KATIE DOWNIE, KEITH SHEPHERD

Introduction

Resilience of rural societies is an important priority of the global development community. It features prominently in the program documents of aid organization, and enhancing resilience is the declared objective of many development activities, particularly in Africa. In spite of the increasing attention paid to system resilience, the concept is rather poorly understood, in particular when it comes to its practical application.

Definitions of resilience in development contexts differ slightly, but all revolve around the response of systems to shocks or stressors. While USAID's definition includes the ability of systems to reduce vulnerability and facilitate inclusive growth in response to shocks, FAO is more concerned with reducing sensitivity to shocks. Yet both definitions centrally hinge on the response of systems to shocks and stressors, and this core concept of the resilience definition leads to substantial difficulties in operationalizing the concept.

Shocks and stressors cannot normally be observed in the field. More importantly, the risk emanating from the entire range of possible shocks and stressors, considering the likelihood of their occurrence, can never be observed in the field. Since resilience aims to incorporate the response of systems to the full range of plausible shocks and stressors, this is a central constraint to assessing resilience through observations alone.

To some extent, system simulations with models can overcome this constraint, because use of a model makes it possible to evaluate the system's response to multiple manifestations of reality, considering uncertainties about the system, the natural variability of weather and other stochastic processes and the intensity and likelihood of occurrence of shocks and stressors. However, most systems of interest to resilience-oriented development agents are poorly understood and reliable mechanistic models do not exist. Where such models have been developed, they often rely on large amounts of normally unavailable data, and they include spuriously precise characterization of system processes, which severely constrain the applicability and credibility of the resulting simulations in real-world development contexts.

Faced with the lack of reliable models, resilience researchers have resorted to defining resilience indices based on an understanding of what factors contribute to resilience at various levels. While this approach has produced some notable successes, the array of indicators as well as their relationships has typically lacked robustness, because the choice of parameters was based on literature surveys and researcher intuition rather than on their statistically established correlation with system resilience. Since resilience cannot be observed and appropriate models have not been available, this has been a reasonable approach. Existence of an objective quantification of resilience, derived with a reliable process model, would greatly help decide on the array of indicators that are really critical for system resilience in a particular context.

We propose a new approach to developing such a model. This approach draws from decision analysis procedures typically applied for informing business decisions, which in almost all cases must be made in the face of substantial uncertainties about their outcomes.

Applied Information Economics

Our approach leans heavily on the techniques of Applied Information Economics (AIE)[4], though these will be adapted to suit the needs of the particular challenge at hand. In spite of these prospective adaptations, an overview of AIE will be useful for understanding the general approach.

All business, development and policy decisions are made in the face of multiple uncertainties, and decision-makers who do not want to rely on their intuitions alone need tools to guide them toward sound decisions that consider these uncertainties. AIE provides such guidance. The technical centerpiece of AIE is the simulation of thousands of plausible manifestations of reality spanning the full range of what the respective decision maker deems possible. This technique is typically referred to as Monte Carlo analysis. The simulation model in this process initially represents all relevant system components in an aggregated form, avoiding an overly detailed representation of reality. This approach is desirable, because it allows large numbers of simulation runs, which would not be possible with very detailed models. It also avoids the temptation among modelers to focus too much on exact mathematical representation of processes that are not really well enough understood for making precise equations. The model-building process aims at providing ‘ballpark’ estimates of important variables and relationships, rather than using ‘best guesses’ that would introduce potentially consequential assumptions into the decision analysis process. Rather than modeling any particular process with great detail, it is important to include all factors and processes that are likely to be important for system resilience into the model, regardless of how ‘intangible’ they initially seem. Everything that is deemed important should be represented, though in many cases initially as a component of larger aggregated variables.

For all important input parameters into the Monte Carlo simulations, plausible ranges and probability distributions are defined. These are either extracted from the literature or, in cases where no information is readily available, estimated by calibrated experts. Calibration of estimators is necessary, because most people are not initially very good at estimating confidence intervals. Various techniques

[4] Hubbard DW., 2010. *How to measure anything: finding the value of “intangibles” in business.* 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

are available for improving an expert's ability to make such estimates, and these techniques will be conveyed to experts during calibration training. Once estimates of all important variables are available and a first aggregate model has been developed, a large number of simulations are run, with input variables randomly selected from probability distributions defined by estimated confidence intervals. All results are collected, providing a large dataset of plausible input variables coupled with modeled system outcomes. If system processes are modeled over time, multi-year estimates of food security, household income or ecological integrity of the modeled system allow characterization of system resilience.

Data mining techniques are then applied to identify the input variables that had the greatest influence on modeled system outcomes, including measures of resilience. It is possible to explore different resilience measures or other system outcomes as dependent variables. Statistically established relationships between variation in particular input variables and system outcomes can then provide guidance on which input variables are the main determinants of system resilience. The information derived from this process can mean three things: 1) Uncertainty about the identified variables is large and has a large effect on outcomes, and more information needs to be collected. 2) Outcomes vary with the distribution of the respective input variable, so that, e.g., households with particular characteristics are more resilient than others. This can help in targeting interventions to particularly vulnerable groups. 3) Where system manipulation can shift the distributions for important variables, interventions can be designed that bring about such shifts and improve outcomes.

Where concrete decisions are modeled, variables with high information values for the decision can be identified. Additional measurements of these variables can then improve the ability of a decision maker to make a sound decision and are priorities for research.

Application to the Horn of Africa

The process described above and shown in Figure 1 will be executed for a selected socio-ecological system in the Horn of Africa. The exact location and context is still to be determined. An aggregate-level system model will be developed, and system processes will be simulated over multiple years, while collecting important system outcomes each year. Outcome indicators will be identified to capture resilience at different levels, such as the household scale, the community scale and the ecosystem scale. Details of these indicators will be selected in close collaboration with resilience experts working in the region. These experts will also be used in system model development. This process will start with an operational definition of resilience that derives from simulation of system processes over the entire simulation period. We anticipate that the ability to consider system dynamics over time, as well as probability and magnitude distributions of shocks and stressors, which have not normally been available in resilience assessments, will facilitate the development of such a definition. Procedurally, model development will be an outcome-driven process, starting with the defined indicators of resilience and working backwards toward the parameters that must be estimated. The process thus differs from the more conventional approach of taking information that happens to be available and building a model from it.

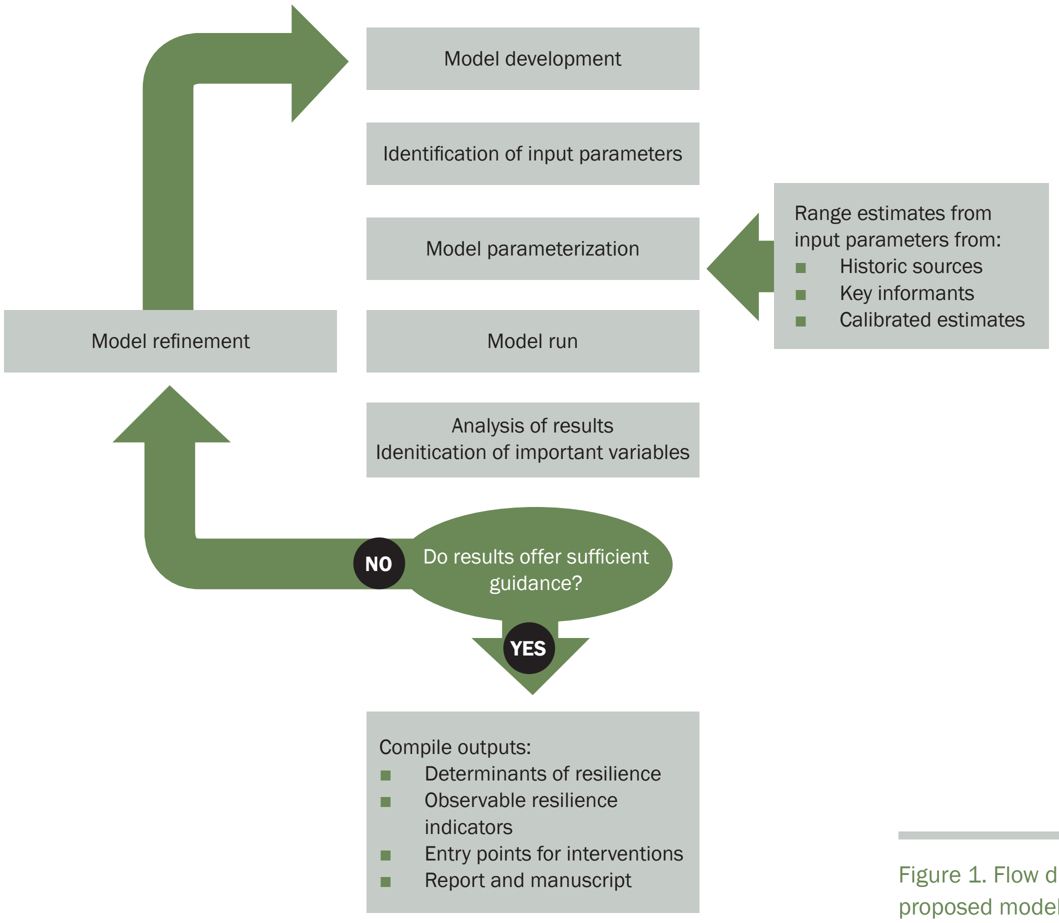

Figure 1. Flow diagram of proposed modeling procedure

Initially, the system model will be simple, focusing on plausible outcomes of system processes rather than on detailed modeling of these processes. For instance, the model might initially consider a distribution of potential maize yields between 1 and 4 Mg ha^{-1}, rather than engaging a computationally expensive crop model that would require a wide range of assumptions about production practices, climate or soils. In model development, an attempt will be made to capture all major factors that affect resilience, regardless of how difficult to measure they might seem. For example, if model builders feel that social networks are important in conveying resilience to individual households, they should appear in the model. It will, however, be necessary to specify how these factors affect system processes. In many cases, this will be highly uncertain, e.g. social networks might reduce a household's risk of destitution in a given year by between 10 and 70%. It is important to state effects with ranges that reflect the estimator's uncertainty. Ranges for system variables will be defined for all factors that emerge during model building, whenever participants feel that it is possible to estimate these ranges.

As soon as all model processes have been defined and all variables estimated, Monte Carlo analysis will be run and results collected. Multivariate data analysis methods will then be used to pinpoint variables of particular importance. It is quite possible that many system variables that have traditionally received a lot of attention in resilience studies will turn out to be of subordinate importance, because they are not major determinants of resilience in the system. A hypothetical example might help illustrate this rather abstract point. At a basic level, household resilience depends (among other things) on the dependability of household income. Household income may be composed of a weather-dependent component (mainly from agricultural or pastoral activities) and a weather-independent component (off-farm income). A system simulation might show that, when considering all uncertainties around both income components, household resilience is mainly determined by availability of off-farm income. In further simulations, it might then make sense to disaggregate the off-farm component into its constituent parts and identify possible interventions in the non-agricultural sector. Detailed modeling of crop growth or herd dynamics or collection of soil data may then not be necessary for determining the main factors that convey resilience, and interventions in the agricultural sector may not be the most efficient strategies to raise resilience.

While the above example may be simplistic, we hope that it illustrates how the modeling process will work. In reality, we expect more variables to be important and more disaggregation of processes to be necessary. However, the exact strategy to take in refining the model after the initial aggregate stage will be determined by the results of the first Monte Carlo simulations. The model refining step will then proceed iteratively, until useful and actionable information about resilience determinants is obtained.

Target outcomes

We should note that this process is somewhat experimental, and engaging in the modeling process largely based on reasonable estimates rather than hard data will require a certain leap of faith by those participating in model building. Yet if successful, this approach should be able to provide robust evidence on resilience that cannot currently be obtained with conventional methods. The procedure will then provide 1) information on the determinants of resilience; 2) information on indicators of resilience that are observable today and could be monitored over time; 3) entry points for promising interventions that increase resilience; 4) a modeling framework that can be used to simulate the effects of interventions on measures of system resilience.

We also anticipate that taking an outcome-driven approach to conceptualizing resilience will expose participants in model building to new perspectives on resilience that are easily overlooked in conventional approaches, which quickly zoom in on particular constituents of resilience without exploring their importance in the overall context of the larger system.

Monitoring the key indictors along the quantified impact pathway over time, especially those variables with high uncertainty, provides a means of accumulating evidence that outcomes can be attributed to the intervention. Monitoring uncertain variables also provides opportunity for early corrective action during intervention implementation. For example, if it is found that actual adoption rates are falling behind projected adoption rates, then the reasons for this can be further modeled and measures put in place to correct course. If the desired outcomes are achieved but actual adoption rates remained well below those projected to be required, then it is unlikely that the outcomes could be attributed to the intervention.

Activities and time line

Model development and execution

Figure 1 presents activities to be completed in the project. The project will start by convening a group of five to ten experts with in-depth knowledge of the specific part of the Horn of Africa that will be selected for detailed analysis. In a 3-day workshop, this group will be exposed to the envisioned model development process and then jointly develop a conceptual understanding of the socio-ecological system of the respective region, with particular attention to what constitutes resilience in the local context. The group will develop flow diagrams that illustrate how the various system components are interconnected and how they are affected by shocks and stressors. The group will also agree on an operational definition of resilience to be used for further modeling. This can include indicators at various levels, and it could even accommodate multiple definitions of resilience. Subsequently, quantitative relationships between model elements will be defined and critical model parameters identified. Strategies will be devised to obtain information about critical variables. These can come from 1) current or historic sources; 2) key informants; or 3) the model developer team. Wherever the model relies on subjective estimates, which will almost certainly be required, prospective estimators will be subjected to calibration training. This will be achieved during a half-day to one-day workshop, which will either be held directly after the initial workshop or later. Remote instruction techniques will likely be used for this workshop.

After coding the initial model, estimates for all critical parameters will be collected from sources identified above. In this process, all uncertain variables will be defined by 90% confidence intervals rather than shooting for 'best bets', which can lead to substantial errors in modeled outcomes. Once all important estimates have been collected, Monte Carlo simulations will be run and results analyzed statistically. Important variables that relate strongly to uncertainty in modeled resilience outcomes will be identified through data mining techniques. It is anticipated that resilience will have been defined either as a composite of various aspects of resilience, or even that different definitions will have been chosen by different group members. In this case, the importance of weighting different constituents of resilience differentially or choosing different definitions will also be explored.

Model validation and refinement

A two-day workshop will be convened to discuss the modeling outcomes with stakeholders in model development. This workshop has two objectives: 1) validation of modeling results; 2) refinement of the model structure. It is likely that changes to the model structure will then be needed, which could consist either of refinement of various model components through further disaggregation of variables or through changes to the broader model structure itself. The model assessment during this second workshop will guide further activities. It may necessitate further rounds of model development, validation and refinement.

Evaluation of model results

Once development and refinement of the model has been finalized and a satisfactory model run executed, results will be analyzed and discussed among the modeling group. The group will then compile the outputs, which are described below. A report will be produced to provide a detailed account of procedures used and results obtained. A manuscript to be submitted to a peer-reviewed journal is also envisioned.

Outputs

A) List of determinants of resilience
This list will contain the variables identified as most important for conveying resilience to the system under study. These may not necessarily be readily observable. Measurements will be proposed that could enhance the predictive ability of the model. These will aim at narrowing confidence intervals for critical input variables.

B) List of observable resilience indicators
This list will attempt to define resilience indicators that could be observed on the ground and monitored over time. There will likely be a lot of overlap between this list and list A, but some compromises may be necessary for important determinants of resilience that cannot be directly observed but assessed via observable proxies.

C) Entry points for resilience-enhancing interventions
Critical variables for resilience will be evaluated with a view to defining interventions. From this assessment, a list will be compiled of possible interventions that could address each critical parameter that emerged from the model.

Overall time frame
12 months

Budget
Approximately USD128,000 (full cost, incl. 2 workshops, staff time, advice from HDR)

4

Report on assessing resilience in the Horn of Africa: an **applied information economics approach**

EIKE LUEDELING, KEITH SHEPHERD, JAN DE LEEUW

Objective

The objective of this project was the application of the Applied Information Economics (AIE) approach to resilience in the Horn of Africa. In order to meet this objective, resilience experts were convened in Nairobi in July 2013. In a facilitated workshop, the principles of AIE were presented to the experts and a participatory model development process started. AIE is a procedure that evaluates the implications of specific decisions, so a concrete decision had to be identified. The group had difficulties agreeing on a case study to work on, which caused substantial delays in the process. Even after about two months of further email discussions, a concrete decision was not forthcoming. It was then decided to focus instead on the Galana Ranch irrigation project in Eastern Kenya. The decision to implement this project was then modeled using a small team of experts chosen from among the participants of the initial workshop. In order to produce sufficient materials for two conference presentations in May 2014, a second case study on borehole management in Kenyan rangelands was also developed.

The Galana Ranch model

The Galana Ranch is a large area of land in the Tana River Basin that the Government of Kenya wants to convert into irrigated agriculture. Specifics of the model that was developed are outlined in a report prepared by Hubbard Decision Research, a partner in the project.

Determinants of resilience

The analysis provided an indication of important uncertainties in the model that should be addressed by further research. The most critical variables, which affect the profitability and resilience of the proposed intervention, were:

- The revenue/cost ratio of proposed farming activities
- The costs of agricultural activities per unit area
- Potential downstream effects
- The value decision-makers attach to preventing a calorie-insecure household
- The value of loss of health

Measurements related to the profitability of farming operations were therefore recommended as the most effective strategy for ensuring long-term viability of the proposed intervention. An assessment of downstream impacts is also recommended.

Observable resilience indicators

For monitoring resilience over time, it would be desirable to monitor developments in farming costs and benefits. Only if farms are profitable in the long run, the irrigation scheme can remain viable. The value of information for variables related to profitability was so much greater than for all other variables in the model, that such measurements should be prioritized. It is recommended that this could be implemented by conducting regular surveys of farming costs and benefits. Farming profitability indicators are also likely to integrate other potential sustainability concerns, such as soil degradation, marketing problems and labor constraints, all of which should affect farm profits.

Monitoring environmental and social impacts in downstream areas is also important, but more disaggregation of variables may be necessary for arriving at specific indicators that can be tracked over time.

Entry points for resilience enhancing interventions

Long-term profitability of farming operations is key to the resilience of the irrigation scheme, so interventions that strengthen farm sustainability and profitability would be helpful. This may be best achieved by the following strategies:

- **Establish research unit for the Galana Ranch**
  A targeted research unit that develops and tests new technologies under the conditions of the Galana Ranch would be useful for ensuring that farms are equipped with profitable technologies. Such a unit appears justified by the size of the irrigation scheme. Given the strategic importance of the scheme for national food security, the Government of Kenya or the concerned counties might consider supporting such a research unit.

- **Effective extension structures**
  Effective extension structures should be set up on the ranch to ensure that farmers are equipped with the knowledge necessary to implement sustainable and profitable practices. This is of particular importance, if the scheme is to rely on a large number of small farmers rather than a few large companies.

- **Effective marketing structures**
  Effective marketing structures for inputs and outputs must be established, so that bottlenecks in the purchase of farm inputs and marketing of outputs can be avoided. This may best be achieved by partnering with the private sector, which could be encouraged to establish a local hub on the ranch.

More details on the model are given in the report prepared by HDR.

Borehole intervention model

The Galana Ranch intervention case had a strong resilience component, but the modeling team was missing information on important aspects of the project, which somewhat undermined the suitability of this decision as a case study. Since two conference presentations were to be given in May 2014 on this project, it was therefore decided to run another analysis on a case, for which information was more easily available. A model was therefore built with a much smaller team (Eike Luedeling and Jan De Leeuw, with inputs from Steven Moiko) to simulate the decision to implement improved management of boreholes in Kenyan rangelands. Improved borehole management is expected to enhance animal survival during drought years and to reduce drought-induced milk yield losses.

In this model, pastoralists derive their income from the sale of animals and milk. Costs considered in the model are those involved with borehole management and emergency responses. Naturally, other costs and probably other benefits occur in the system, but these were assumed to not depend much on the decision to implement better borehole management and they were thus not factored into the decision. Both milk yield and animal offtake depend on herd size and composition, as well as, in the case of milk, the nutritional status of animals.

This model simulates herd size by combining a herd dynamics model with the simulated carrying capacity of the land (as a function of climate). Whenever herd size exceeds the carrying capacity of the land, certain responses are triggered, including emergency sales, emergency aid and higher mortality. Drought occurs when simulated herd size exceeds the carrying capacity by a certain amount. In such cases, price effects occur, assuming that animal prices drop during such times, and milk yield per cow declines. The effects of improved borehole management, as well as the effect of emergency aid are simulated by a reduction of herd mortality by a certain percentage.

All variables entered the model as uncertain quantities. Simulation results indicated that the likelihood of improved borehole management providing net benefits was very high, compared to a small chance only of negative effects (Figure 2).

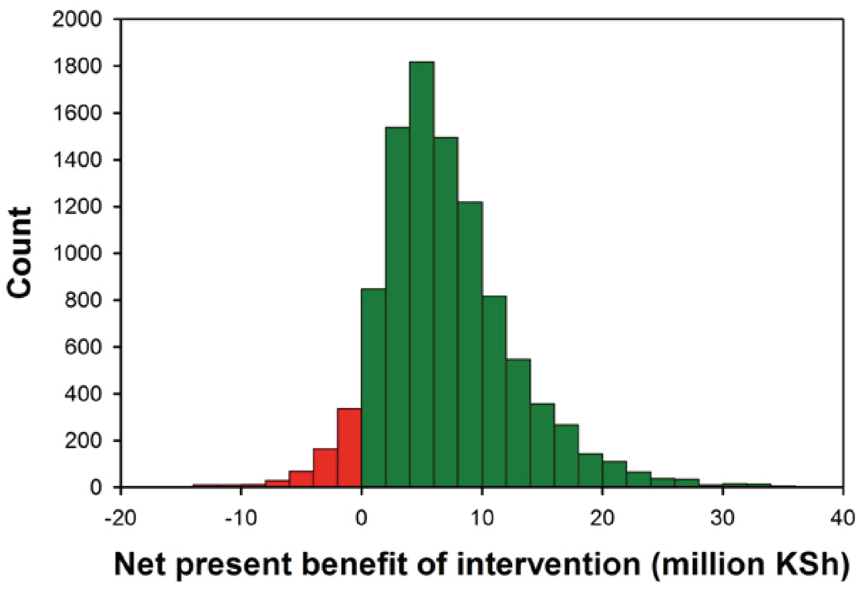

Figure 2. Net present benefit distribution of improved borehole management in Kenyan rangelands for an exemplary borehole. The distribution was derived from 10,000 runs of a Monte Carlo simulation.

Determinants of resilience

The greatest source of uncertainty about the ability of the borehole intervention to enhance system resilience was the time preference of the pastoralists, as indicated by their discount rate. If this rate is very high, interventions aimed at averting future losses are not valued highly, because immediate returns are prioritized. Further sources of uncertainty, in order of priority, were the mean milk price, the mortality reduction capacity of the intervention, the normal growth rate of the herd and the milk yield in a normal year.

Important variables in the livestock model, in order of importance, are listed below:

- Discount rate
- Mean milk price
- Mortality reduction capacity of improved borehole management
- Normal herd growth rate
- Milk yield in a normal year
- Mean carrying capacity in a normal year
- Drought severity that reduces milk yield
- Percentage of lactating cows in the herd
- Carrying capacity variability (coefficient of variation)
- Maximum animal offtake (sale) during drought
- Mortality reduction capacity of emergency aid
- Mean cost of emergency aid

Observable resilience indicators

A creative indicator of resilience may be the discount rate of the population, because it mirrors the ability and aptitude to plan for the future. Its measurement is tricky, however, making its suitability as an indicator uncertain.

The simulation showed that for evaluating the capacity of the intervention to improve system performance over the long term, monitoring of the milk economy is a promising approach. Uncertainty about the price of milk was a major constraint to precision in predicting system outcomes. This was mainly because milk may be marketed formally, in which case prices would be high, or used mostly for subsistence, which would imply that realized prices are low. Monitoring the returns from milk would provide valuable insights.

Similarly, effectiveness of the intervention, as well as of emergency relief, in reducing herd mortality, deserves attention. Establishing clearer figures on this emerged as a priority, and this may best be achieved by monitoring the performance of such interventions. This would, however, not strictly be a resilience indicator, rather than an uncertainty reduction.

The ability of pastoralists to sell animals during a drought emerged as an observable indicator. It seems likely that most herders would attempt to sell animals during drought, and their well-being will likely depend on the number of animals they can sell quickly, even in an oversupply situation, as may result from a severe drought.

Entry points for interventions

The model focused on the decision to manage boreholes better. This clearly emerged as a promising intervention.

- Strengthening of the milk economy
  Improving the ability of pastoralists to supply their milk to higher-priced markets would be desirable. This could probably be achieved by expanding cooling chains and facilitating collection of milk from mobile populations.

- Offtake support
  A key bottleneck to resilience to drought was identified in the ability of pastoralists to sell animals in times of drought. This could be a promising entry point for an intervention, which could target the ability to slaughter, cool and transport many animals quickly. This would primarily require investments in infrastructure, but could also consist of provision of support for entrepreneurs focusing on the pastoralist meat value chains.

Conclusions

There is no doubt that the inability to find a suitable case study slowed the project down. Furthermore, since the cases that were modeled were theoretical, without involving decision makers or people with profound inside knowledge of the irrigation intervention, it was difficult to find representations of the decision implications that would be particularly credible.

Nevertheless, modeling the decisions was quite successful and the resulting models should mirror the expertise and the level of confidence of the involved experts reasonably well. Even without high accuracy or detailed expertise, it became quite clear that taking the interventions forward would be the preferable scenario.

It was also apparent that collection of data on a few variables would greatly enhance certainty that a particular decision alternative is preferable over the other. Based on the uncertain variables with the greatest uncertainty implications, areas for intervention could be identified. These are key uncertainties that do not necessarily result from insufficient information, but rather from uncertainty about how exactly the intervention will be executed. Such variables offer potential for designing interventions. This analysis attracted attention to the profitability of farming operations in the Galana case, as well as the milk economy in the rangeland intervention.

The way forward

All activities undertaken in this project to date were useful exercises that helped adapt the Decision Analysis methodology to the resilience context. The analysts' understanding of resilience in the Horn of Africa and of stakeholder needs was further sharpened during discussions about the models, as well as during consultations with the National Drought Management Authority of Kenya, and with stakeholders in resilience to climate change convened by the

CGIAR's CCAFS program. Discussions during the 'Resilience 2014' conference in Montpellier, France, and the IFPRI 2020 conference on 'Building Resilience for Food and Nutrition Security' in Addis Ababa, Ethiopia, helped further sharpen understanding of the resilience context, which will greatly help in building a future model about a real decision case. Steps towards work on such a decision have been undertaken, and talks are currently ongoing between the Technical Consortium (represented by Constance Neely of ICRAF) and UNICEF to agree on a decision context to focus on.

Further project outputs

- Report on Galana Ranch model (compiled by Hubbard Decision Research)
- Conference paper at the Resilience 2014 conference in Montpellier, France
- Conference paper at the IFPRI 2020 conference in Addis Ababa, Ethiopia

Annex 1

Decision modelling framework for the reduction of uncertainty: A concept note on the use of decision analysis tools to model the impact of investment on enhanced resilience in the Horn of Africa

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The past decade in the drylands of the greater Horn of Africa has been marked by repeated droughts, triggering recurrent crises of food insecurity and rising concern about the effectiveness of long term development prospects. Large numbers of people and livestock have been negatively affected during each of these episodes; over the past decade the Horn has experienced droughts in 1999-2000, 2005, 2008-9 and 2010-11.

Pastoralists living in these drylands produce large amounts of livestock, satisfying demand for meat and milk not only within the IGAD region but also serving an export market to the Middle East. Pastoral and agro-pastoral producers have taken advantage of new market opportunities, communication technologies and better infrastructure to diversify their livelihoods, improve their livestock production and hence incomes. It is estimated that 90% of all animal and animal products destined for export from the Horn originate in pastoral lowlands. The drylands are also home to remarkable biodiversity, including wildlife and birds that support a thriving tourist industry, often in direct synergies with livestock.

Governments, the Inter-governmental Authority on Development (IGAD) and development partners are faced with a complex development problem: how to support the productive potential of the Greater Horn of Africa drylands and end the cycles of poverty and food insecurity?

In mid-2011 donor and national governments began a concerted effort to end the cycle of drought-related emergencies. In mid- September 2011 the Government of Kenya hosted a Heads of State meeting at which all IGAD members committed to Ending Drought Emergencies and IGAD was given the mandate to coordinate regional interventions. IGAD subsequently established the Drought Disaster Resilience and Sustainability Initiative (IDDRSI).

One of the key features of initiatives that emerged from consultations between IGAD, regional governments and development partners was a focus on "resilience," or the ability of households, communities and systems to manage change or adapt to stresses, without compromising future development prospects[5,6]. A resilience approach to development seeks to go further than solely reducing vulnerability, and aims at preventing repeated stresses and shocks from undermining development prospects. A key element of a resilience approach is, therefore, to understand and address the underlying short and long term factors that contribute to vulnerability and poverty.

[5] IRWG, 2012. *Characteristics of Resilience: A Discussion Paper*. p.12.

[6] Frankenburger, T.R. et al., 2012. *Enhancing Resilience to Food Insecurity amid Protracted Crises.* p.18.

Resilient growth and development focuses more holistically than traditional development on a systems-oriented approach and seeks to simultaneously strengthen institutions and socio-economic assets and make agro-ecological systems more robust, enabling a range of actors to better manage risk and uncertainty, thereby reducing the vulnerability of populations. Vulnerable households have multiple needs (social protection, land access, income generating opportunities, etc.) and thus no single sector intervention is sufficient. Furthermore, individuals or communities are part of complex and adaptive systems, and a holistic approach to planning is needed to manage risk, reduce vulnerability, and balance short-term needs with long term concerns.

A first step in building resilience is to understand the causes of chronic vulnerability. In the Horn, the root causes of vulnerability of livelihoods is complex, as households are vulnerable to multiple stressors, some of which are chronic and structural, and others such as drought, which are periodic but trigger food insecurity crises. These crises and the increased chronic poverty occur as a result of the inability of households to cope, both in the short and longer term, with the impact of droughts on agro-environment, livestock assets, household income and consumption. These drivers are a combination of political neglect of basic services, human and livestock population pressures, growing land fragmentation coupled with constraints on access to water and fodder and an increase in rangeland degradation, periodic large and small scale conflict and insufficient policy and institutional support for pastoral livestock production and viable long term economic development[7].

While evidence exists to support the benefits, both in terms of cost and impact, of longer term investment and the shifting paradigm from response to prevention[8], analytical frameworks[9,10,11] for better evaluating how investments will enhance resilience are needed. The Technical Consortium (TC) has been tasked with supporting IGAD and the IDRRSI in developing a set of Monitoring and Evaluation (M&E) tools which will inform the M&E components of not only the investment planning documents, but help set the stage for evaluation for impact towards resilience, investment prioritization and assessing return on investment for all actors working in the Horn. To date, the TC has assisted IGAD and member governments to prepare a country-level results framework, which has been incorporated into the RPP/CPPs, a M&E framework for the World Bank financed Regional Pastoral Livelihoods Resilience Project (RPLRP) and is developing an innovative approach to the financial and economic analysis of that planned investment. These processes will inform the development of additional tools to measure impacts of interventions on resilience, including:

i) A framework for measuring resilience and a set of indicators that represent a systematic contribution towards resilience;
ii) A methodology for prioritization of investment for interventions that influence resilience and a means of assessing return on investment; and
iii) National baseline datasets for IGAD Member States.

In order to develop these tools and frameworks it is critical to understand the systems involved in determining resilience and the variables, within and without, which, by their interaction within and across systems, produce a cumulative impact (see Figure 3). Identifying the dependent variables within these systems and quantifying and attributing the effect of their dynamic interaction on resilience is necessary to understand what types of interventions, in what sector, will best enhance resilience.

[7] Davies, J., 2008. Turning the tide: Enabling sustainable development for Africa's mobile pastoralists. *Natural Resources Forum*, 32 (3), p. 175–184.

[8] Cabot Venton, C. et al., 2012. *The Economics of Early Response and Disaster Resilience: Lessons from Kenya and Ethiopia*. Nairobi.

[9] Alinovi, L., Mane, E. & Romano, D., 2008. *Towards the measurement of household resilience to food insecurity: applying a model to Palestinian household data.* Deriving Food Security Information from National Household Budget Surveys. Rome: Food and Agriculture Oganization of the United Nations (FAO), p. 186.

[10] Frankenburger, T.R. et al., 2012. *Enhancing Resilience to Food Insecurity amid Protracted Crises*. p.18.

[11] Fraser, E.D.G. et al., 2011. Assessing Vulnerability to Climate Change in Dryland Livelihood Systems: Conceptual Challenges and Interdisciplinary Solutions. *Ecology and Society*, 16(3 C7 - 3).

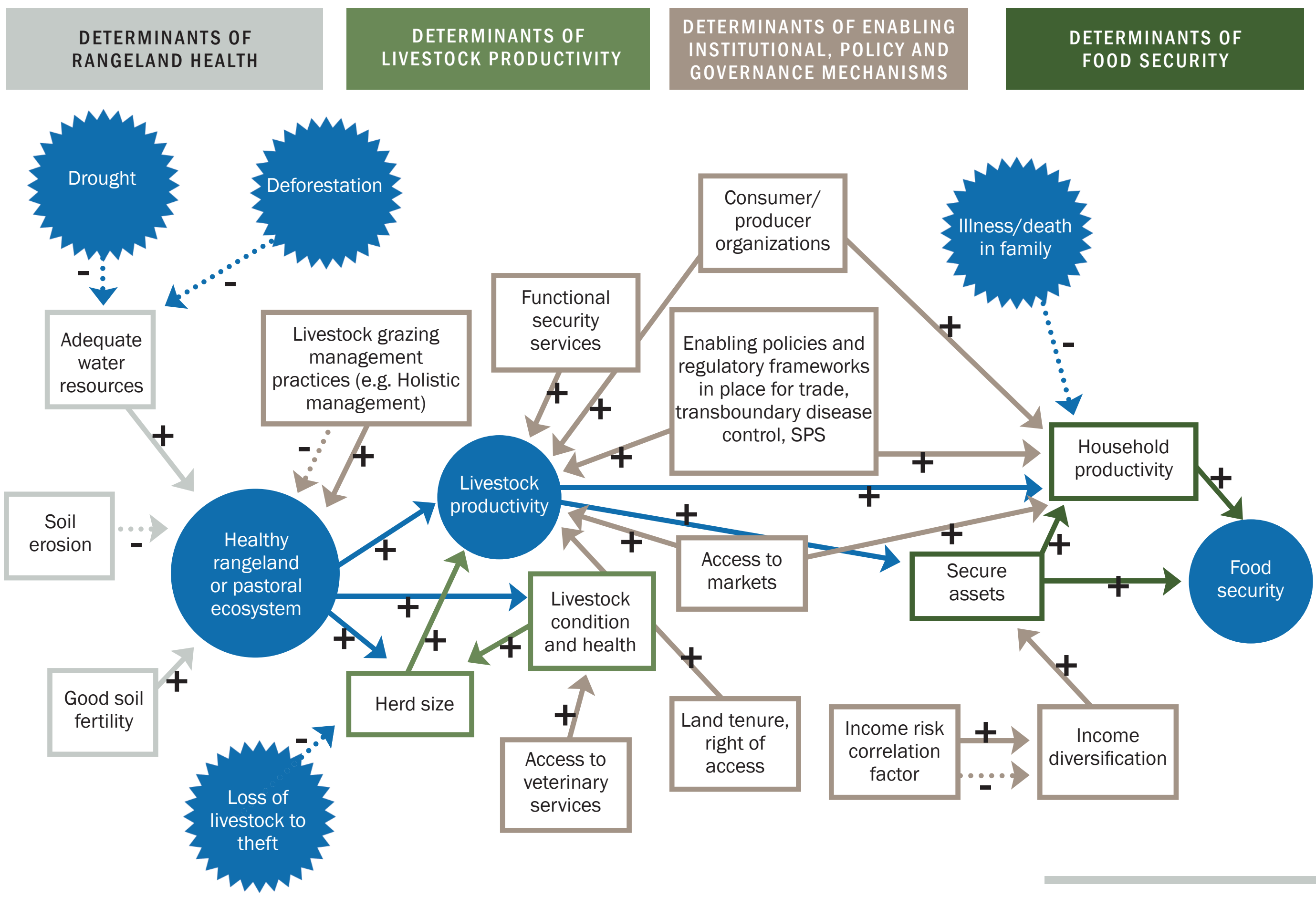

Figure 3: Potential systems, variables and respective impacts on resilience or food security: an attempt to illustrate complexity in dynamic interaction of variables

An FAO-WFP sponsored Expert Consultation on Resilience Measurement for Food Security, which was held in Rome in February 2013, identified ten key resilience measurement principles, indicating that resilience:

1. Is a dynamic process
2. Is context-specific — evaluators must always ask “resilient to what” and “resilience among whom”
3. Changes over time — measurement should be based on panel data if possible
4. May operate non-linearly, making critical tipping points important to capture
5. Should be measured by those who have the technical capacity to conduct complex analyses
6. Measures should account for cultural factors
7. Operates at multiple levels including individual, household, and community levels —measurement and data collection methodologies should reflect these levels
8. Measures should consider the dynamics between the different levels on which it operates
9. Is comprised of psycho-social factors, in addition to more traditional economic factors
10. Measures should capture the state of natural resources in a given community[12]

[12] Taken from “Why evidence-based resilience measurement is more important than ever” by Tiffany Griffin, M&E Specialist, USAID. April 22nd, 2013. http://agrilinks.org/blog/why-evidence-based-resilience-measurement-more-important-ever

Baseline data requirements

The TC has been working closely with research partners within the CGIAR, FAO and other external agencies to develop accurate and functional baseline datasets for the Horn. One of the activities the TC is prioritizing is to conduct a meta-analysis of available data in the region held by relevant stakeholder institutions.

The first phase of this activity will involve assessing data at multiple scales comprising multiple indicators and sectors (e.g. agricultural (crops and livestock), spatial bio-physical layers (soil, climate, farming systems, etc.), population and poverty data, national household surveys (LSMS, FSAU and livelihood zone monitoring and agricultural census, including input uses, farm characteristics, nutrition, rough animal stocks), government and development partner commitments and disbursements, etc.). A classification and categorization architecture will be developed, in alignment with ongoing efforts from other data analysis activities such as the ICRAF/DfID Open Data for Agriculture in Africa survey, FAO GIEWS, USAID FEWSNET, WFP Comprehensive Food Security Vulnerability Assessment (CFSVA), the Food Security Information Network (FSIN), UNICEF Multiple Indicator Cluster Surveys and those within other CG centres such as IFPRI and Harvest Choice.

The second phase of this project will be the mapping and spatial analysis of the existing data to reveal geographical dispersion at multiple levels and scales and, based on revealed gaps, inform next steps to take with respect to further data collection.

The final deliverable from this exercise will be national baseline datasets at household level, maintained and populated by the IGAD Member State governments. A methodology for the continuous collection and maintenance of these datasets will have been developed, tested and operationalized for use by Member States.

Why is measuring resilience difficult?

While the impact of non-resilience in the face of disaster is measurable and very instructive to policy makers – the Kenya post-disaster assessment has shown that the country had lost USD 12.8 billion and some 2.8% of growth a year over the years 2009-2011[13] – resilience itself is difficult to measure as:

- Resilience cannot be represented by one, easily defined or quantified variable. It is rather, the accrual of multiple variables across multiple systems that, in their dynamic interaction, represent the ability of interconnected systems to maintain their system resilience and identity, while contributing to an outcome which represents this cumulative product.
- Resilience is highly contextual and the current linear and causal socio-ecological models could be strengthened to accommodate the micro, meso and macro processes of the relationships between stressors, components of household, social, political (community) and ecological capital and outcomes. Building resilience is rarely a linear, cumulative process, increasing as each composite component improves. The dynamic interaction between components or variables is critical. An increase in one variable may produce, sometimes drastic, reductions in another,

[13] Cabot Venton, C. et al., 2012. *The Economics of Early Response and Disaster Resilience: Lessons from Kenya and Ethiopia*. Nairobi.

resulting in an overall drop in resilience. Examples of well-intended drought mitigation measures which could, in fact, result in unintended prolongation of unproductive livelihoods are; the continuous restocking of households for whom livestock production has ceased to be sustainable, or the introduction of productive safety nets in a similar livelihood scenario. Attempting to anticipate and understand these dynamics and their impact on resilience is a major challenge.

- Disaster resilience also implies the need to measure how the variables affecting resilience are affected by disturbance. Again, the range, nature and magnitude of disturbances affecting populations in the ASALs are multiple. Modelling the actual or potential impact upon resilience adds another layer to the whole measurement model. It entails identifying not only resilience but resilience to what?
- Finally the overall goal of the IDDRISI strategy is to create "disaster resilient communities, institutions and ecosystems". This means any resilience monitoring framework needs to outline how resilience should be measured (with all the aforementioned challenges) for each of these units of analysis. It is not clear whether the variables that affect and result in community level resilience are the same as those that make an eco-system or an institution resilient. Even the term 'community' needs to be clearly defined when establishing the appropriate monitoring data required to measure disaster resilience.

Challenges to measuring resilience: some questions

Which variables from which system will be of use in determining resilience of system and resilience of household, community etc.? Which variables are essential? How can we determine what these are?

Resilience is a multi-sectoral and multi-dimensional concept, with many potential variables – socio-economic, political, environmental, physical, climatic etc. – which different proponents justifiably claim to affect resilience. Consequently there is much debate over which variables constitute the most important elements of any measurement tool. Clearly any practical monitoring framework cannot measure all the potential variables (even if data were to exist). What criteria could or should be used to prioritise and synthesize potential options?

The availability, quality and coverage of data for all disaster affected areas of the HoA are a chronic problem. Some countries have very limited standard data collection processes due to years of conflict and weak governance e.g. Somalia, South Sudan. The sparse populations of the ASAL areas mean national level monitoring of many development indicators is not done at a scale that allows for differentiation across livelihood groups, ecological zones or wealth groups within the ASALs. Therefore, even if key variables are identified the ability to monitor them may be limited.

How can we model the dynamic interaction of variables intra- and inter-system to ascertain their impact on resilience? How can we develop a framework that can accommodate the contextuality of scenarios?

The dynamic nature of the variables impacting upon resilience raises a major challenge for IGAD Governments and other donors. It is not enough for any monitoring framework to measure absolute and relative levels of resilience as an end state, although understanding the developmental impact would certainly be useful. Given the current lack of understanding as to what policies or interventions most effectively and efficiently build resilience, the framework also needs to capture the variables that confer a resilient state. This means policy makers don't just want to know if resilience has been achieved but how the target group got there. This will enable policy makers to 'diagnose' the factors or variables that need to be impacted by interventions in order drive changes in resilience.

How can we quantify some of the more intangible variables and measure their impact on resilience and their dynamic interaction?

Many of the variables identified as critical to resilience are rather intangible and do not lend themselves easily to quantitative measurement. Typical examples include governance, security, social capital or eco-system health. Indicators do exist in all these areas but there is no, or limited agreement as to which best represent impact and few are comprehensively monitored. Hence there is no mechanism for consolidating and comparing findings.

To help answer meet these challenges to measuring resilience, the Technical Consortium is proposing to test a decision analysis approach, which is elaborated below.

How can Decision Analysis Tools be applied to the Horn of Africa resilience agenda?

A recent CGIAR review of global monitoring systems in agro-ecosystems and livelihoods concluded that there is little evidence that initiatives have had impact on decision making and proposed a decision analytical framework for the design of new initiatives[14]. In partnership with Hubbard Decision Research, the CGIAR has proposed an intervention decision modelling framework (IDM) for estimating the impact of interventions, determining how to measure and monitor development outcomes, and showing the value of research[15]. The framework applies the Applied Information Economics (AIE) approach developed by Hubbard Decision Research[16]. The IDM is currently being applied to a sample of six cases across the strategic research portfolios of the CGIAR Program on Water, Land and Ecosystems[17], including sustainable intensification or rainfed agriculture including pastoralist systems. The Horn of Africa project will be integrated into this framework, with a focus on measurement of resilience and modelling of portfolios of investment options. Key elements of the approach are summarized below.

- **Clarify the decisions that measurements will support.** The need for data should be determined by the specific decision these data will inform. Once a decision is clarified, the data requirements become more apparent. Experience with the CGIAR decision analysis cases has shown that development workers and researchers find this step difficult and there needs to be substantive effort devoted to clarifying the decisions they seek to influence, and the specific decision alternatives being considered.

[14] Shepherd, K.D., Farrow, A., Ringler C., Gassner A., Jarvis A., 2013. *Review of the Evidence on Indicators, Metrics and Monitoring Systems.* Commissioned by the UK Department for International Development (DFID). Nairobi: World Agroforestry Centre. http://r4d.dfid.gov.uk/output/192446/default.aspx

[15] Shepherd K.D. and Hubbard D.W. 2012. *The Need for an Intrenvention Decision Model.* Concept Note. World Agorofrestry Centre, Nairobi.

[16] Hubbard DW., 2010. *How to measure anything: finding the value of "intangibles" in business.* 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

[17] http://wle.cgiar.org/

- **Model the current state of uncertainty.** Representing the uncertainties on all variables facilitates inclusion of important variables that are often ignored because they are seemingly too difficult to measure. The consequences of the uncertainty in variables are assessed using "Monte Carlo" simulation and a special method for training experts to assess probabilities. This initial model is effectively a snapshot of the current state of uncertainty about a problem before additional measurements are made.

- **Determine the "information value of variables and the identification of high value variables in a decision".** Not all variables in a decision model are worth measuring and those worth measuring are often a surprise to the decision makers. In fact, sometimes, a kind of "measurement inversion" exists in decisions – that is, the most uncertain variables tend to be ignored while the variables that usually receive a lot of attention frequently have less bearing on the decision. With AIE, every variable in a model will have an "information value" that allows identification of high value variables in a decision. This approach targets only the variables in a decision that are the most likely to significantly reduce overall uncertainty in the decision.

  The complexity inherent in dynamic social-ecological systems often hinges upon the interaction of three to six critical variables and processes that operate over distinctly different spatial and temporal scales[18]. Decision analysis tools can assist in isolating these variables.

- **Measure What Matters:** Once the high-value measurements are identified, a variety of empirical methods can be used. Contrary to what is sometimes assumed, relatively little data or simple observations may be required for extremely uncertain variables. AIE often uses efficient "Bayesian" methods, which exploit prior knowledge and can be used even when data is messy or sparse. The measured variables will have less uncertainty and then the model of uncertainty can be updated. Variables with higher information values are also those that need closest monitoring during implementation, as those are the variables most likely to drift off course.

- **Make Better Decisions:** Research shows that the actual risk aversion and other preferences of decision makers changes frequently and unconsciously. Different preferences are applied to different investments even when management believes they are being consistent. AIE addresses this major source of decision error by quantifying and documenting preferences such as risk tolerance and the value of deferred benefits so that the results of analysis can be assessed in a controlled, uniform manner. In this case, decisions may have large combinations of outcomes and have to be part of a portfolio of decisions. When necessary, AIE applies optimization methods to determine the best decision even from a large set of alternatives.

Forecasting intervention impacts is valuable in several stages: (i) investment prioritization (which investment alternatives best contribute to system level outcomes; what information can most reduce uncertainty and improve intervention decisions), (ii) design of portfolio of investment (how can adjusting the intervention design reduce risk of negative outcomes), (iii) implementation

[18] Gunderson, L. & Holling, C., 2002. *Panarchy: understanding transformations in human and natural systems*. Washington, DC: Island Press.

(which variables are most likely to go wrong and so should be most closely monitored), (iv) impact assessment (if measured variables match projected variables then you have accumulated evidence for attribution).

The modelling approach should provide a rationale for assessing potential impacts of investment by sector on enhancing resilience. This rationale is necessary to guide decision-making processes for sectoral intervention prioritization in investment planning documents such as the IGAD Member States' Country Programme Papers and could assist considerably in aligning other investment initiatives (World Bank, IMF, AfDB, etc.) in the region in an improved common Monitoring and Evaluation framework, including common impact variables.

Decision analysis activities

5. Convene a workshop of researchers and experts, supported by Hubbard Decision Research, with the following objectives (2nd week of July):

5.1. Expose the group to the Applied Information Economics Methods (0.5 day instruction).

5.2. Clarify the decision problems to be addressed drawing on country plans. Choose one pilot decision problem for developing and demonstrating the overall approach (1 day).

5.3. Define dimensions of resilience in relation to the decision problems and identify variables to measure them (1 day).

5.4. Define important variables for the models.

6. Identify a core group (including relevant stakeholders) who will contribute to further model development and provision of estimates.

7. Provide calibration training to the modelling group and anyone who will be providing estimates.

8. Develop a pilot decision model (preferably for a portfolio of investment alternatives) to further develop the approach. Document the model and approach into a report (complete by Dec 2013).

9. Identify a set of additional decision problems and teams and apply the modelling framework (2014).

Annex 2

Decision analysis tools meeting: Final Agenda

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Decision Analysis Tools
Applied Information Economics
9-11 July 2013
Room 720, ILRI, Nairobi, Kenya

Day 1: Introduction to AIE. Choose the pilot decision to be modeled.
Day 2: How to measure resilience and include it in the model.
Day 3: Start defining model variables. Identify core modeling group.

Day 1: July 9th 2013

0830-0900	Registration and Coffee
0900-1030	(Large Group) Introductions and familiarize the group with the Applied Information Economics Methods (0.5 day Discussion and Presentation).
1030-1100	Tea Break
1100-1230	*continuation of morning session*
1230-1400	Lunch
1400-1530	(Large Group) Clarify the decision problems to be addressed drawing on country plans. Confirm/choose decision problem for developing and demonstrating the overall approach (0.5 day).
1530-1600	Tea Break
1600-1700	*continuation of afternoon session*
1700	Closing of Day 1

Day 2: July 10th 2013

0830-0900	Registration and Coffee
0900-1030	(Small Groups, morning) Define dimensions of resilience in relation to the decision problems and identify variables to measure them (0.5 day)
1030-1100	Tea Break
1100-1230	*continuation of morning session*
1230-1400	Lunch
1400-1530	(Large Group, afternoon) Define dimensions of resilience in relation to the decision problems and identify variables to measure them. (0.5 day)
1530-1600	Tea Break
1600-1700	*continuation of afternoon session*
1700	Closing of Day 2

Day 3: July 11th 2013

0830-0900	Registration and Coffee
0900-1030	(Small Groups, morning) Define important variables for the models.
1030-1100	Tea Break
1100-1230	*continuation of morning session*
1230-1400	Lunch
1400-1530	(Large Group, afternoon) a. Define important variables for the models. b. Identify a core group (including relevant stakeholders) who will contribute to further model development and provision of estimates. c. Identify scope of work for the future and roles and responsibilities.
1530-1600	Tea Break
1600-1700	*continuation of afternoon session*
1700	Closing of Day 3

Post-workshop:

Provide calibration training to the modeling group and anyone who will be providing estimates.

Annex 3

Decision analysis tools meeting: List of participants

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technical consortium
Building Resilience in the Horn of Africa

The Technical Consortium for Building Resilience in the Horn of Africa provides technical support to IGAD and member states in the Horn of Africa on evidence-based planning and regional and national investment programs, for the long-term resilience of communities living in arid and semi-arid lands. It harnesses CGIAR research and other knowledge on interventions in order to inform sustainable development in the Horn of Africa. www.technicalconsortium.org