Spatial analysis for investment targeting: PILOT TOOL UNDER DEVELOPMENT
The term ‘resilience’ has gained significant traction within the agencies, governments, researchers and practitioners working across the development and humanitarian realm. Resilience is seen as a paradigm shift, away from short-term thinking and solutions to address vulnerability to hazards such as drought. Instead, interventions that, over a longer time, can enhance development and build capacity to deal with dynamic environmental and social challenges and enduring shocks and stresses. In response to this paradigm shift and following the humanitarian disaster caused by the 2010-2011 drought crisis in the Horn of Africa, the Summit of the Heads of State and Government convened in Nairobi in September 2011 to launch “Ending Drought Emergencies”. And, in the spirit of a new-found sense of optimism, the member states of the Intergovernmental Authority on Development (IGAD) committed to a program of work for which a significant outcome would be the enhanced resilience of populations residing in the drylands of the Horn of Africa. This initiative, after decades of the affected countries being overwhelmed by emergencies, manifested their commitment to end drought emergencies and vulnerabilities from the IGAD region once and for all.

Most definitions of resilience in development scenarios hinge upon the response of social, ecological and economic systems to shocks and stressors. It is, however, extremely difficult to quantify this response, as it is impossible to observe the full range of possible disturbances, hence assessments of system resilience normally fall short of providing comprehensive evaluations. In addition, as building resilience is rarely a linear, cumulative process that increases as each system component improves, the current linear and causal socio-ecological models used to measure resilience are inadequate to understand these micro, meso and macro interactions. For example, an overall loss of resilience may be caused by an increase in one variable producing a drastic reduction in another. Furthermore, resilience can be viewed over varying spatial scales such as individuals, households and communities, and over varying temporal scales such as seasons, years, or years in a program lifespan, from immediate to long-term. This variance may make it necessary to continually update panel datasets.

The Resilience Measurement Technical Working Group defines resilience as follows: “Resilience is the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences.”

One of the key features of this definition is that resilience is understood and measured according to the instrumental effects it exerts on targeted development outcomes that may be affected by stressors and shocks. Defining resilience as a capacity means that resilience is comprised of a set of ex ante attributes and supports that should positively shift the likelihood function that describes the relationship between shocks and development outcomes, such as food security. Resilience is seen as a paradigm shift, away from short-term thinking and solutions toward interventions that, over a longer time, can enhance development and build capacity to deal with dynamic environmental and social challenges.
**Purpose**

In order to better measure resilience, and to better understand and target investment that will enhance resilience, the Technical Consortium is developing a pilot spatial tool. The purpose of this resilience modeling tool is to assist IGAD member states in the Horn of Africa in identifying areas of high and low resilience to known hazards, initially focusing on resilience to drought specifically. This identification of relative levels of resilience geographically will provide an opportunity for better targeting of investment projects proposed by those datasets that could populate the indicators isolated in the systems review and indicator selection. Eventually these data catalogues will provide governments with meta-data on indicators that are generally agreed to contribute towards “resilience” to drought in the Horn of Africa.

For the purposes of this model, resilience is understood as the ability of a population to recover from a shock. This ability is based on a calculation of the initial vulnerability at the time of the shock and target investment that will enhance resilience, the Technical Consortium's work to establish catalogues containing baseline datasets for the IGAD member state countries, a data inventory for the region that carried out, entailing extensive consultation with agencies, NGOs and governments in the Horn of Africa to collate available information on data sources. The data scoping resulted in 452 datasets being acquired and reviewed and indicator selection. Eventually these data catalogues will provide governments with meta-data on indicators that are generally agreed to contribute towards “resilience” to drought in the Horn of Africa.

**Review of spatial baseline datasets**

In order to represent vulnerability or susceptibility and time to recover, and as part of the Technical Consortium’s work to establish catalogues containing baseline datasets for the IGAD member state countries, a data inventory for the region that carried out, entailing extensive consultation with agencies, NGOs and governments in the Horn of Africa to collate available information on data sources. The data scoping resulted in 452 datasets being acquired and standardized in order to be comparable and scalable between values representing highest and lowest resilience. The systems framing these baseline datasets are designed as social, economic and ecological.

Over a six-month period, a robust scoping for available datasets was undertaken, entailing extensive consultation with agencies, NGOs and governments in the Horn of Africa to collate available information on data sources. The data scoping resulted in 452 datasets being acquired and standardized in order to be comparable and scalable between values representing highest and lowest resilience. The systems framing these baseline datasets are designed as social, economic and ecological.

Figure 1 (below) provides an example of just four of the 452 datasets acquired – namely groundwater productivity, predicted areas of suitability for Tsetse fly, interest rates and the mortality rate of children under 5. It illustrates how each available dataset in a System, Composite Indicator, Indicator and ISO Topic. The availability of the relevant dataset in each of the IGAD member states (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Former Sudan and Uganda) was noted, noting with the dataset’s spatial extent, spatial resolution, resolution unit, etc.

Various tests of the utility value of the datasets in terms of their scale, resolution, integrality and other attributes, were carried out. One of these tests involved the production of 10 maps at different scales (regional, national and subnational), looking at spatially representing basic indicators such as distance to water, livestock numbers, access to education and health etc. From this exercise, the limitations of the available spatial data were better understood and the requirements to generate more useful data were recognized.
To improve livestock productivity and soil quality, annual plant production in arid and semi-arid lands (ASALs) is crucial. Livestock population crashes in the Horn of Africa, a model was developed to simulate livestock population dynamics in the region with an emphasis on the lower trophic interaction between herbivores (livestock) and their vegetation food base, in gauging future livestock populations. The model also provides an understanding of the lower trophic interaction between herbivores (livestock) and their vegetation food base, in gauging future livestock populations. The model assumes that only 15% of total understorey biomass is relevant to livestock10 as much of it will either harden/lignify without being consumed, be removed by insects or be overhawked by herbivores in favor of fresh green growth.

The model therefore provides a high spatial resolution representation of relevant phytomass or the plant building blocks for annual growth. In the ASALs, these ‘building blocks’ for fresh growth exist as woody or inedible rhizome material that persists as standing crop from one season to another. The building blocks are not fixed from year to year, but may accumulate in years of good rainfall or decline during drought. This separation of persistent and more variable fresh growth is analogous to the concepts of capital: winter phytomass = biomass = capital (which can appreciate or depreciate) and annual plant production = fresh growth = interest.

Phytomass at the end of a year was modified by a factor which varied between x 0.9 (driest years) and x 1.3 (wettest years). The value used was directly (linearly) interpolated from the rainfall anomaly. This created a rapid variation in livestock population estimates as the factors ranged from 0.37362% of phytomass (equivalent to 0.3736 of biomass). Food supplies or carrying capacity for the livestock can then be calculated as all of the fresh growth plus 10% of the phytomass, assuming that one tropical livestock unit consumes 2500 kg DM per annum7.

For paraking foods for the supply for the exceed total demand of livestock consumption, it was assumed that there was no depletion of capital due to livestock. If consumption exceeds food supplies, then the exact deficit (less...
15% to be found elsewhere) was subtracted from capital. For each grid cell, livestock numbers at start (P) are compared with the carrying capacity (K), where K or carrying capacity is not a fixed long-term stocking rate but a highly dynamic measure that realistically represents prevailing food conditions based on rainfall for that year and cell. The P:K ratio is then used to scale both livestock recruitment and livestock mortality in a linear fashion ranging between the extremes of worst case scenario and best case scenario and values for a ‘normal’ year. The assumption is that mortality rates will be maximum and recruitment rates minimum when large livestock populations are stressed by drought; and that mortality rates will be minimum and recruitment rates maximum when small livestock populations experience good rains.

Map outputs were produced for phytomass and production in an average year. The coefficient was calculated of the variation of livestock mortality rate to highlight which parts of IGAD arid regions regularly face the most dramatic increases and decreases of livestock numbers due to rainfall patterns. This was used in the environmental sensitivity layer along with the expected mortality rate for 2014 (based on average rainfall pattern) and a measure of livestock overhead going into 2014. Animations were also produced to visualise the pattern of change in model parameters over the 30 years of rainfall data. Output layers were checked for particular grid cells from one year to the next to ensure the calculations were made correctly.

It is hoped that the model will prove useful as an early warning system for livestock mortalities in arid parts of Africa. For 2014, an input of rainfall data in a ‘normal’ year can forecast mortality patterns if rainfall follows an average course. The rainfall patterns have also been determined from strong El Nino and La Nina years, which can be fed into the model if sea surface temperatures in the Indo-Pacific indicate one of these patterns is imminent. There is thought to be a nine-month advance warning from these indicators. The model is in its pilot development stage, with ground truthing and expert consultation on its parameters still required as part of a larger validation of the spatial tool.

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**Review of systems, selection of indicators**

The next step in developing the spatial tool was to synthesise the system indicators. As mentioned previously, in order to represent vulnerability or susceptibility and time to recover, spatial datasets were grouped into three systems: ecological, social and economic. The ecological system refers to the natural resources that we use and depend on, that are provided by nature as opposed to being human engineered. The social system is defined as the level of community/social support, or the level of access to ‘human capital’, while the economic system is defined as access to material wealth.

From the pool of datasets, 165 indicators were selected that best represent resilience in these three key systems. The 165 resilience indicators were selected using the following underlying criteria:

- relevance to the region’s resilience,
- data quality and
- availability of the data on a regional and national level.

The indicators were then divided amongst the three systems: social (51), economic (73) and ecological (41) (see Figure 3 on following page).

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11 This selection of indicators and the datasets to populate them has to date been based largely on expert judgement. More validation of the weighting will take place within the next six months.
Rationale behind methodology

Systems and indicators were separated to better measure and assess the influence on resilience that each may have.

Ecological conditions (such as rainfall and population density) define the susceptibility of a particular location to the impact of a shock, such as severe drought. Assessing the ecological/environmental system indicators of an area is the first step in evaluating that area’s resilience.

Social (non-material) conditions and economic (material) conditions affect the adaptive capacity of a particular location/community to bounce back from the environmental shock once it has occurred. Therefore, social system indicators (good governance, inclusivity in decision-making, access to good healthcare) and economic system indicators (road and rail infrastructure, access to market, GDP per capita) form an important means of evaluating the time a community needs to rebuild or bounce back after the shock has occurred.

In many cases variables may be relevant both during and after a shock, it was expedient for the purposes of developing the tool to allocate ecological or environmental indicators in a first step to evaluate susceptibility to the shock; and to allocate social or economic indicators in a second step, which could evaluate time to rebuild following a shock. These steps are later combined in evaluating overall resilience so they are still included whether considered during or after the shocks.

Weighting of indicators

Once the indicators were separated into the three systems, careful consideration was then given in assigning weights to each indicator in order to compose an overall index of resilience. Each indicator was weighted using an ArcGIS Model Builder, which allows for easy changing of weightings at two classification levels for future sensitivity analysis.

The method of combining these datasets involved standardizing the scale of each to vary in integer values ranging from 1 to 9, and then a simple summation of the values is the first step in evaluating that area’s resilience. Each indicator was weighted using an ArcGIS Model Builder, which allows for easy changing of weightings at two classification levels for future sensitivity analysis.

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The indicators were then combined into composite indicators, in order to allow for multiple overlays, in line with GIS mapping capability. An ESRI Model Builder was used to assemble these data into six composite indicators for ecological/environmental (water resources, land use, ecosystem services, per capita resources, climate and natural resource shocks); four composite indicators for social (health, education, governance and social shocks); and seven composite indicators for economic (infrastructure, trade access, financial services, wealth, financial conditions, livelihood/income diversification and economic shocks).

The composite indicators are illustrated over the next three pages.

On the opposite page:

Figure 4: Overview of the composite indicators within the spatial tool.
The spatial tool analyzes the resilience layers for each of the administration districts that are submitted in the query and produces a summary table containing the following information:

1. **Area** of the administration district
2. **Population** of the administration district (calculated from AfriPOP 2010 adjusted UN)
3. **Susceptibility/Impact**: mean value of the ecological or environmental system layer (as indicated by the weighting of its ecological indicators). Low impact equates to high resilience, while high values of impact equates to low resilience, at the time of the environmental shock. Values are relative; they are not interpreted in any other way.
4. **Time to Recover**: We took the mean value of the socio-economic systems layer (as indicated by the weighting of its social and economic indicators) and we inverted these values so that high socio-economic capacity represented an expected shorter time to recover following a shock. Short recovery time values equate to a high resilience, while long recovery time values equate to low resilience. Values are relative; they are not interpreted to actual time.
5. **Overall Resilience**: calculated by combining susceptibility with measures of recovery time (this is computed as socio-economic capacity for recovery divided by environmental-sensitivity or susceptibility to the shock). Areas with high capacity for quick recovery and low susceptibility to the shock are accorded highest resilience; while areas poor in capacity for recovery and highly susceptible to the shocks are accorded lowest resilience.

The output is then illustrated as a regional map (see graphic on right), showing locations where environmental shocks are expected to have a higher impact and affected communities will take a long time to recover (highlighted in red), and areas where shocks have a lower impact and communities will be quicker to recover (highlighted in blue).

**Spatial outputs**

In Phase 1 of the spatial tool, generic shocks are considered that may occur anywhere in the IGAD region—taking into account that many shocks (especially economic and social shocks) have a broad geographic focus.
Future developments of spatial tool

In Phase 1 of the spatial tool, generic shocks are considered that may occur anywhere in the IGAD region – taking into account that many shocks (especially economic and social shocks) have a broad geographic focus. However, the tool has been designed to accommodate a likelihood of occurrence maps for shocks that occur in specific areas. These shocks will be calculated in Phase 2 of the spatial tool, which focuses on drought as the primary hazard.

The Horn of Africa is predominantly comprised of arid or semi-arid lands, and is a naturally drought-prone region. With increasing pastoral or agro-pastoral land use, the environment and pastoral communities in this region are progressively susceptible to severe drought. In particular, heavy stocking of the land and consequent overgrazing will extend existing droughts, while denuded vegetation is the primary cause of further desertification and an increase in future droughts. This imbalance of livestock requirements and pasture availability results in livestock mortalities and food security issues.

It is therefore imperative that such pastoral communities be resilient to an environmental shock such as severe drought, in order to sustain food investments, such as the promotion of stock movement and reduction, will be calculated in Phase 2 of the spatial tool, which focuses on drought as the primary hazard. Version 2 highlights pastoral and agro-pastoral localities where farmers and dependents may be at risk of significant livestock mortalities in the short-term. It is based on short-term rainfall estimates at high geographic resolution and encompasses the outputs of the livestock-vegetation model developed for the Horn of Africa Resilience Project. These outputs are confined to the pastoral and agro-pastoral land use regions.

Version 2 will include a new, high-resolution drought exposure layer: the existing time to recover layer; and a modified environmental sensitivity layer. It is envisaged that this version will be used to target those areas in which investments, such as the promotion of stock movement and reduction, will achieve optimal impact.

The Technical Consortium is collaborating with model developers at Colorado State University, to combine elements of their G-Range model\(^{12}\), which simulates and forecasts rangeland ecosystem processes with this module to fit within the spatial tool. Version 2 identifies geographical areas in the Horn of Africa with respect to their resilience across multiple sectors using medium to long-term data on drought exposure risk. It is based on a new drought exposure layer: based on longer-term datasets, a subset of relevant environmental sensitivity layers, and the existing time to recover layer. It is envisaged that this version will be useful to potential investors considering a variety of sectors e.g. water management, early warning information systems, conflict reduction.

Both versions will combine population estimates with the calculation of resilience in order to focus potential investments on those areas that will see the biggest impact in terms of people helped. The outputs will be similar to those already produced by the spatial tool: a summary map and spreadsheet.

Version 2 may be developed into an early warning system for livestock farmers if the datasets are updated and with possible linking to the Southern Oscillation Index (SOI). Discussions are in place regarding the possibility of a ‘futures analysis’ that can factor in projected climate change, loss of cropland etc.

The advance overlay functionality of GIS and the resulting spatial outputs will form an integral aspect for both the rational targeting of investment and the building of capacity and baselines from which to measure the impact. Historic and recent datasets were provided as benchmarks, which may then be tracked through time for the early detection and identification of anomalies or thresholds, the crossing of which may precipitate regime shift to a less favorable state. Summary and other datasets have been supplied for each member state to augment and integrate with existing regional environmental information systems with the purpose of informing high spatial resolution decisions about land use and resilient development for populations within the ASALs.
ILRI works to improve food security and reduce poverty in developing countries through research for better and more sustainable use of livestock. ILRI is a member of the CGIAR Consortium, a global research partnership of 15 centres working with many partners for a food-secure future. ILRI has two main campuses in East Africa and other hubs in East, West and Southern Africa and South, Southeast and East Asia. ilri.org

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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. technicalconsortium.org