# Sustainable Microforestry

## An adaptive management tool for smallholder agroforestry farms in Ganze District, Kenya

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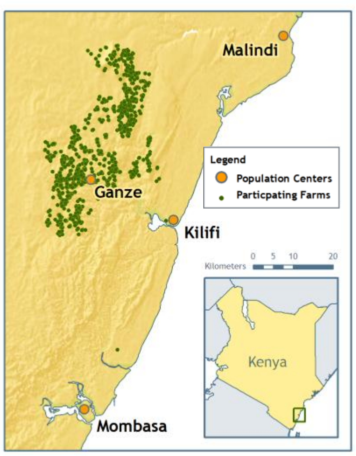
## Overview

Ganze District, Kenya, is a dryland area that faces serious issues of poverty and land degradation. KOMAZA, our client, is a non-profit organization that aims to alleviate poverty in the region by helping farmers plant and sell high-value eucalyptus trees. The purpose of this project is to provide our client with a tool that will help it more effectively alleviate poverty by improving the decision-making abilities of its staff. Poverty is the primary driver of local land degradation, so by helping our client return greater profits to its participating farmers, we aim to not only improve the livelihoods of hundreds of impoverished families but also reduce environmental degradation in the region.

## Background

Ganze District is a semi-arid agricultural region in Coast Province, Kenya, with poor soils and minimal infrastructure. Environmental degradation is threatening the livelihoods of the smallholder farmers that live in the region, as most farmers are very poor and depend on the land for survival. However, as these farmers attempt to raise themselves out of poverty, they often turn to the charcoal trade or expand and intensify their farming to supplement their families' incomes.


Agricultural intensification and charcoal-driven deforestation have led to increased land degradation, which reduces the land productivity that the farmers rely upon. As a result, farmers have inadvertently created a positive feedback cycle where poverty and environmental degradation continue to drive one another. In order to break the cycle of poverty and environmental degradation, a source of income is needed that is both economically and environmentally sustainable.


## Project Client

Our client, KOMAZA, is a non-profit social venture that works to alleviate poverty in Ganze District. The organization aims to break the cycle of poverty by partnering with local farmers to generate income through small-scale agroforestry. With support from KOMAZA, individual farm families plant, harvest, process, transport and sell eucalyptus trees as high-value wood products in nearby markets. All of the profit is delivered to the participating farmer, with KOMAZA recouping its costs at the sale of the trees. In this way, farmers are able to drastically increase their incomes without resorting to charcoal-making or other destructive practices.

KOMAZA

## The Problem

KOMAZA is a young organization, founded in 2006, and the trees that it has established have not yet reached the maturity needed for harvesting. As a result, KOMAZA has limited resources, data, and experience with which to inform its management decisions. Without these resources and knowledge, KOMAZA is unable to predict tree growth and profit on a site-by site basis, given the widespread uncertainty in local environmental and market conditions. This leaves KOMAZA unsure which management decisions are necessary to maximize profit. This knowledge gap makes it especially difficult for KOMAZA to plan strategically and adapt its forestry strategies to the range of conditions currently faced by its participating farmers. Additionally, this makes it difficult for KOMAZA to manage the expectations of its farmers and investors, which is necessary to ensure community engagement and participation in the endeavor.

## Project Objectives

1. **Create a flexible tool to aid decision-making**
2. **Demonstrate the various functions of the tool**

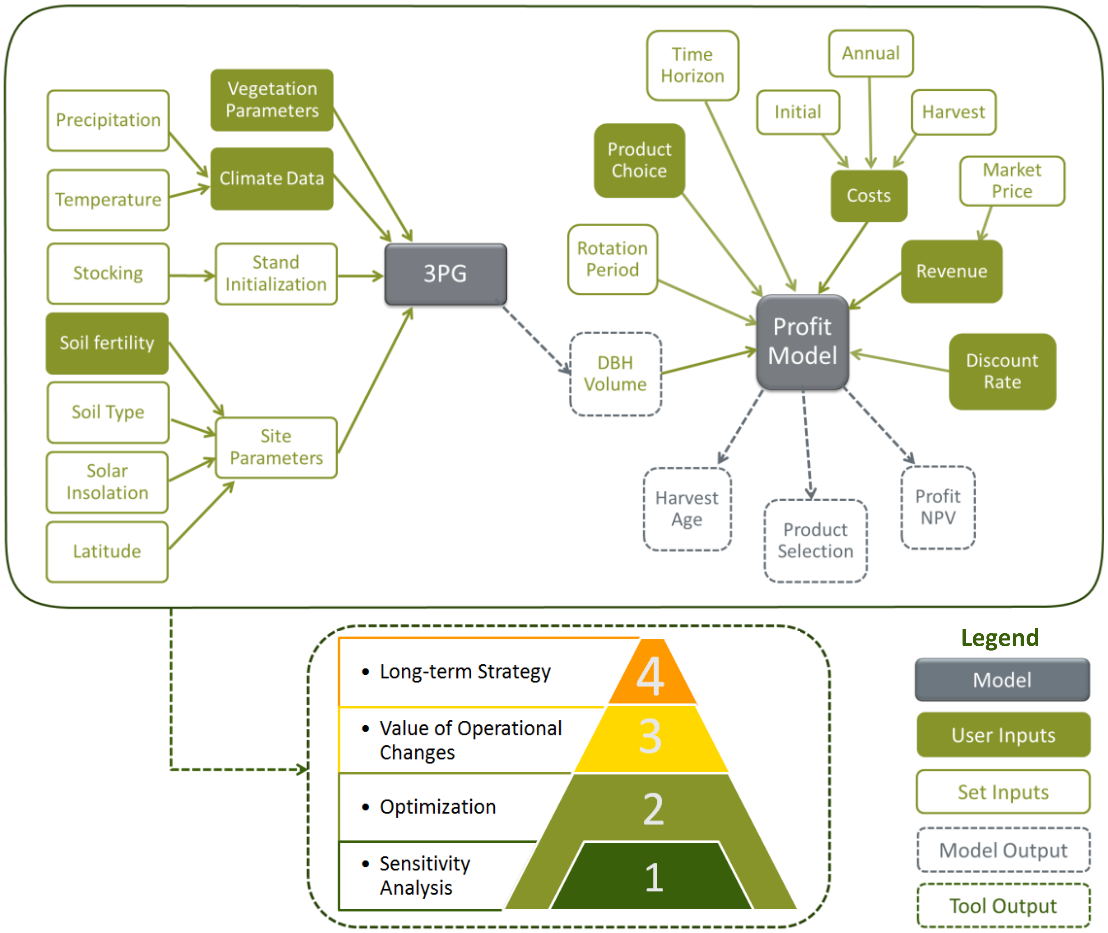
In order to help KOMAZA address this issue, our team developed a flexible, easy to use tool and user interface for estimating forest productivity and expected profits.
In addition to creating the tool, we have provided KOMAZA with a demonstration of the major functions that the tool provides, and how these functions can be used to aid KOMAZA's management decisions. This tool allows KOMAZA to explore the impacts that variations and uncertainty in local environmental and market conditions will have on the profitability of its operations.

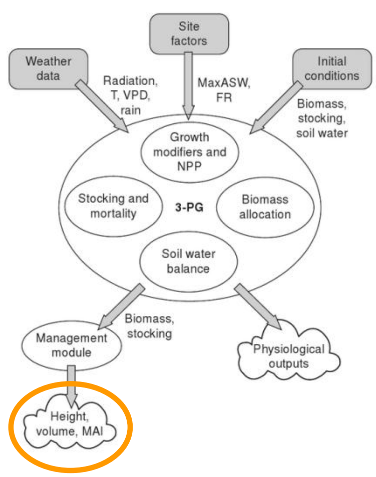
# Creation of the GaPP Tool

## Overview

The Growth and Profit Prediction (GaPP) Tool is a tool and user interface that estimates tree growth and the profitability of KOMAZA's operations under a variety of user-defined scenarios. The tool is built from the integration of two different models. The first is a widely used biophysical model developed by Landsberg and Waring in 1997 called the Physiological Principles Predicting Growth, or 3PG model. This model determines the expected amount of forest growth over time. The second model is one that we created ourselves to calculate profit under a range of scenarios. Together, these two models combine to estimate tree growth and the profitability of KOMAZA's operations under a variety of possible conditions that may be present in Ganze District.

## The GaPP Tool




## About 3PG

The 3PG model determines expected tree growth based on inputs such as climate and soil fertility. We used the 3PG model because it is open source and has outputs easily understood by forestry managers such as KOMAZA.

## Creation of the Profit Model

The Profit Model was developed to estimate the expected value of a series of harvests over a given time horizon. The Profit Model consists of three primary steps:

1. **Generate Scenarios**
2. **Calculate Profit**
3. **Optimize Harvest Age and Product Selection to Maximize Net Present Value of Profit**

## Profit Model (Continued)

The first step is the generation of scenarios, with one scenario for every combination of user-defined input parameter values. The profit of each harvest is then calculated for each scenario. The model maximizes the Net Present Value (NPV) of each harvest by determining the harvest age and product(s) that yield the greatest profit discounted over the set time-horizon. Mathematically, the Profit Model is a series of imbedded functions that describe the relationships between each input parameter as shown in the box below.

**Objective:** Maximize NPV by changing Harvest Age (age) and Product

**Constraint:** Revenue and Cost functions must use the same product

$$NPV =$$

$$\sum_{t=1}^{T} D_{time,discount\ rate}\left[\begin{matrix} R_{product}\left(G_{climate,fertility,vegP,rotation\#,age}\right) \\ -C_{I\ rotation\#} - C_{A\ age} - C_{H\ product,rotation\#}\end{matrix}\right]$$

$t$ = time in years, $T$ = time horizon, $D$ = Discount factor, $R$ = Revenue function, $G$ = 3PG Growth model function, $C_I$ = Input Cost function, $C_A$ = Annual Cost function, $C_H$ = Harvest Cost function

# Using the GaPP Tool

## The Four Functions

The GaPP Tool has four primary functions that help KOMAZA develop and optimize management decisions at every organizational level. These functions can be used to estimate profit under different economic and environmental conditions as well as different farmers' choices of when to harvest and which products to market. Specifically, the tool can be used to 1) identify sensitivity to model parameters, 2) optimize current practices under a set rotation period for different scenarios, 3) model the expected value of operational changes, and 4) analyze long-term strategic management approaches.

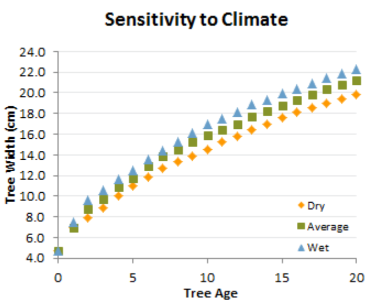

## Demonstration of the GaPP Tool

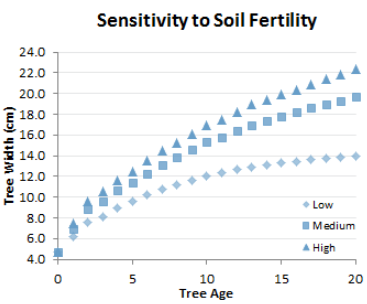
One implementation for each tool function is shown below in order to demonstrate how KOMAZA can use the GaPP Tool. These examples are a select few out of the many examples we provided to KOMAZA in our full report.

### Function 1: Sensitivity Analysis

*Determining the effect of a change in inputs or environmental conditions on tree growth and/or profit*

**Example:** Sensitivity of growth to soil fertility and climate. As shown below, we found that soil fertility has a greater impact on tree growth than climate.

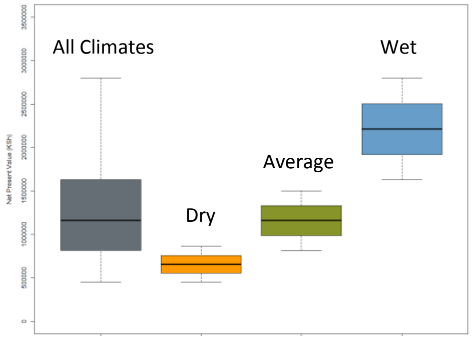



### Function 2: Optimization

*Optimizing harvest age and product selection to maximize profit*

**Example:** Expected maximum net present value (NPV) of profit for multiple scenarios given uncertainty in revenue and climate (gray boxplot). When climate is known (or assumed), the range of expected profit decreases (orange, green and blue boxplots).



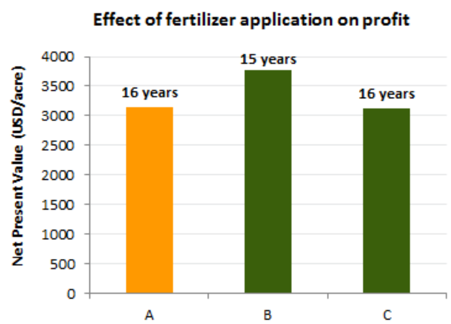

**Uncertain**
Revenue
Climate

**Assume**
Low Costs
Medium Discount
High Soil Fertility

### Function 3: Value of Operational Changes

*Calculating expected value of changes to operational procedures*

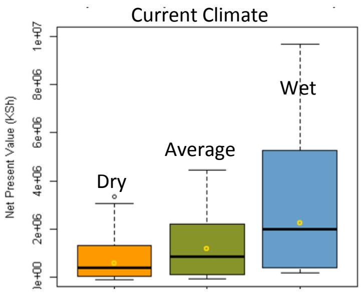
**Example:** Effect of new fertilizer procedure on expected profit. Scenario A below shows regular application of fertilizer constant over the life of a tree. If the application of this same volume of fertilizer is concentrated in early years, overall growth increases, adding value (B). Applying less fertilizer later in the tree's life has no significant effect on profit, but requires less total fertilizer (C). This demonstrates the tradeoff between using a procedural change to increase profits or to reduce potential environmental impacts (through lower fertilizer use).

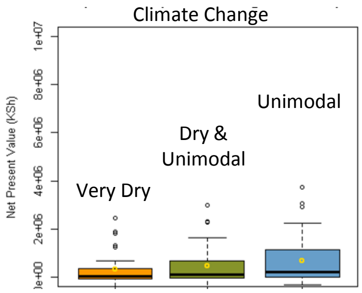



### Function 4: Long-term Strategy

*Developing strategic long-term management plans*

**Example:** Effect of climate change on expected profit. Overall, our analysis showed that profits will decrease under modeled climate change scenarios.



## Discussion

The GaPP Tool takes the first steps towards fulfilling KOMAZA's need for better information about the expected tree growth and profitability of its efforts.
Our initial implementation of this tool shows that the optimal harvest age, product selection, and operational decisions are likely to change under different scenarios and local conditions. This suggests that it is important for KOMAZA to be able tailor its plans to individual farms, in addition to managing the entire organization at a large, regional scale.

This project designed the GaPP Tool so that it:

1. **Provides informed decision-making under conditions of uncertainty,**
2. **Has a user-friendly interface, and**
3. **Offers analyses across multiple planning horizons.**

These characteristics allow the GaPP Tool to offer analyses that are relevant to various decision-makers throughout KOMAZA's team (see top right). The fact that it was created to have a simple, two-page interface is therefore one of the tool's critical strengths. Increased user-friendliness means that less time is needed to understand and adopt the platform, making it more likely that KOMAZA employees will be able to integrate this tool into their decision-making process.

The GaPP Tool also effectively fills KOMAZA's knowledge gap caused by a lack of resources and a lack of experience, and allows the organization to predict profit on multiple scales despite uncertainty in environmental and market conditions. We expect that the improved decision-making capacity will lead to better management decisions  and allow the organization to extend the positive impacts of its efforts. By ensuring KOMAZA's financial stability, this Tool will enable KOMAZA to invest in other projects and goals, such as improving environmental sustainability or focusing on farmer education and awareness.

Ultimately, we believe that the added value of our tool to KOMAZA's planning capacities will help KOMAZA ensure its financial sustainability while providing economic stability to as many farmers as possible in an environmentally sustainable way. Our hope is that our tool helps KOMAZA improve farmers' livelihoods, breaking the cycle of poverty and reducing environmental degradation in Ganze District and beyond.

## Key Strengths

The GaPP Tool offers relevant analyses to various decision-makers in KOMAZA's team, from data collectors to the CEO.

Tool Function 1 will allow **George, KOMAZA's Information Manager,** to strategically invest resources in refining inputs of high uncertainty and impact in order to improve strategic planning and decision-making.

**Erin, a Project Manager with KOMAZA,** can use Tool Function 2 to maximize profit for farmers under their current practices, and use Tool Function 3 to make changes to operations that will create additional value for an individual or series of farms.

Tool Function 4 will enable KOMAZA to effectively scale up its business over time, improving the financial opportunities for as many farmers as possible in an environmentally sustainable way, which is of utmost importance to **Tevis, Founder and CEO of KOMAZA**.

## Takeaways

- **The GaPP Tool provides a clear way to determine the best management option under conditions of uncertainty.**
- **The GaPP Tool offers analyses across spatial and temporal scales, offering KOMAZA's planners the flexibility to apply a management decision at a regional scale or on a site-by-site basis.**
- **The GaPP Tool provides a systematic way to analyze trade-offs between profitability and environmental concerns.**

## Next Steps

Future improvements to the GaPP Tool should be made to ensure that the tool stays relevant and valuable in aiding KOMAZA's key management decisions.

**Specific areas of improvement include:**

- **Direct Modeling of Environmental Impacts**
- **Validating Model Against Observations**
- **Monte Carlo Sensitivity Analysis**

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For more information, please visit our website at http://www2.bren.ucsb.edu/~kenyaplanit/ or email us at kenyaplanit@lists.bren.ucsb.edu.