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Using technology to build affordable business intelligence for the SWP market

Leveraging remote sensing analysis to inform market players

OCTOBER 2021

Image credit: Shell Foundation

Disclaimer

This project intended to further innovation in the solar water pump market in East Africa. Its purpose was to develop and then test the viability of a toolkit that leverages remote sensing to generate affordable business intelligence for the nascent solar water pump market. The objective is for this initial research to pave the way for further work that will build on the immense potential of this approach by expanding it onto multiple geographies and crop types. This study shows how the newly available data can be used to improve targeting of high potential market segments, build financial offerings that best fit the individuals' needs, and respond to policy objectives at the regional and national levels. However, by addressing existing market inefficiencies, its primary objective is to improve the allocation of assets and thereby improve the overall gain to the society, reduce the cost and make the solar water pump market more competitive.

In the pursuit of these objectives, the project is not intended to meet the standards of academic research but rather explore the insights that can be gained from remote sensing data and establish its value for market actors. All results and analyses are based on a small pilot sample and have been validated through a survey. The conclusions drawn are indicative of the actionable business intelligence that can be produced rather than scientific evidence.

Acknowledgments

UKaid from the British people · Efficiency for Access · IKEA Foundation

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Glossary

Crop simulation model (CSM) - a simulation model that describes processes of crop growth and development as a function of weather conditions, soil conditions and crop management.

Remote sensing - the acquisition of information about an object or phenomenon without making physical contact with the object, in contrast to in situ or on-site observation. The term is applied especially to acquiring information about the earth.

Return on investment (ROI) - a ratio between net income (over a period) and investment (costs resulting from an investment of some resources at a point in time). A high ROI means the investment's gains compare favorably to its cost. As a performance measure, ROI is used to evaluate the efficiency of an investment or to compare the efficiencies of several different investments.

Segmentation - (market) segmentation is the process of dividing a broad consumer or business market, normally consisting of existing and potential customers, into sub-groups of consumers (known as segments) based on some type of shared characteristics.

Machine learning - is the study of computer algorithms that can improve automatically through experience and by the use of data. It is seen as a part of artificial intelligence.

Vegetation indices - is a single number that quantifies vegetation biomass and/or plant vigor for each pixel in a remote sensing image

Source: Wikipedia

Content

About the project

Exploring alternative data sources to provide market insights for the solar water pump sector

This report presents field-tested ideas of how remote sensing, machine learning and agricultural simulations can assist in closing data gaps on dispersed smallholder farmers. Low availability and high cost of business data acquisition are some of the main constraints preventing market actors from efficiently serving customers and building successful business offerings. The report, therefore, studies innovative analytical approaches to produce actionable business insights at scale.

The low unit value of transactions made with smallholders necessitates low marginal costs of data acquisition for viable business intelligence. Therefore, traditional data collection methods, such as in-person or phone surveys, are not always appropriate. Further, high dispersion and heterogeneity of the market and lack of sampling frames can make traditional data collection expensive and largely unrepresentative.

This study is enabled by advancements in remote sensing technology and research on its applications in agriculture. It is now possible to gain a relatively precise picture of conditions on the ground using satellite imagery and agricultural simulators without the need for extensive verification with in-person visits. Therefore, the potential of this approach, in the case of business analytics in developing markets, is immense. In this project, we attempt to test the readiness, potential and possible application of this technology to assess the profitability of solar water pumps for smallholder farmers.

Overview of approach

Automating interpretation of observed values with agricultural system simulations as the source of ground truths

The core of our model is an agricultural systems simulator that we use to model the growth of plants based on a parametrization of soil, weather, farming practices and available assets. Our link between ground truths and simulations are vegetation indices.

The richness of the simulations allows us to study outcome characteristics beyond yield. Among the most relevant are soil degradation, produce quality and climate resilience. From these variables, we can derive estimates of farm cash flow and income. In addition, the simulations enable us to quantify the potential impact of changes in farming practice: the benefit of solar water pumps and irrigation equipment in general, different quantities and types of fertilizers, different kinds of seeds, intercropping vs mono-cropping, and timing adjustments of interventions during the season.

Producing these analytics at the farm level enables a multitude of applications. We can leverage the information to improve risk assessments and lower the cost of credit scoring. To identify locations where a subsidy for an asset such as a solar water pump would be most effective in raising farm incomes and finding areas most vulnerable to climate change and natural disasters.

Testing of the approach

Proving the viability of the approach by building and testing an analytical pipeline, setting the direction for further research

We interviewed solar water pump (SWP) users, including delineating their irrigated land to verify findings and anchor them in a real setting. We used a small sample (6) of maize farmers who recently purchased a SWP and irrigated their maize plots. We then matched them with 183 auxiliary, algorithmically identified plots to serve as a control group. These intervention plots were relatively small, with an average size of 0.7 hectares. Maize plots constituted the main crop by area for the studied farmers.

We then derived an example analysis to serve key stakeholders in the market. The analysis demonstrates how to derive crucial business intelligence data at a lower cost, with fewer biases and is a methodologically consistent approach. We then show some major applications of this new data, specifically how to build: location intelligence tools, pricing and credit methods, personalized product offering matching individual user-profiles and measurements of socio-economic impact in real-time.

This study does not offer immediately implementable solutions but proves - through a small pilot - that creating valuable tools based on remote sensing technology is feasible. It, therefore, establishes a direction that individual players can take to improve their decision making and increase the profitability of their businesses, reduce wastage of resources and achieve policy objectives. More data collection is required to increase the robustness and accuracy of this approach.

Background

Introduction

Findings & Applications

Appendix

Problem statement: The information gap on the solar irrigation market hinders its growth

There is an information gap that undermines the SWP market in Sub-Saharan Africa. Successful market building requires information that market players can base their decisions on. Solar water pumps can be highly profitable investments in dry or variable climates with enough solar radiation, but little information is available to determine profitability at scale.

MARKET POTENTIAL

- Sub-Saharan Africa has immense potential for solar technologies, with high and constant amounts of solar radiation.
- Low mechanization level is a crucial barrier to scale smallholder farmers. Sub-Saharan Africa has a quarter of the world's arable land but only 10% of the world's agricultural output[1]. Affordable solar technologies can address improved mechanization for productivity.
- Accessible and cost-effective modern irrigation could shield nearly 500 million small-scale farmers worldwide from poverty, food insecurity and exposure to climate risk[2].

BARRIERS TO GROWTH

- Solar irrigation distributors struggle to penetrate new markets or optimize targeting of customers due to a lack of national, regional and micro level market insights.
- Specifically, market players do not know the value and distribution of the potential gain that their assets can generate, making it challenging to design the right offering.
- Data collection using in-person visits is costly when users are dispersed, remote small-holders with low levels of market connectedness.

1. IFAD, 2021, The Field Report https://www.ifad.org/thefieldreport/
2. E for A, 2019. Solar Water P ump Outlook 2019: Global Trends and Market Opportunities. https://efficiencyforaccess.org/publications/solar-water-pump-outlook-2019-global-trends-and-market-opportunities

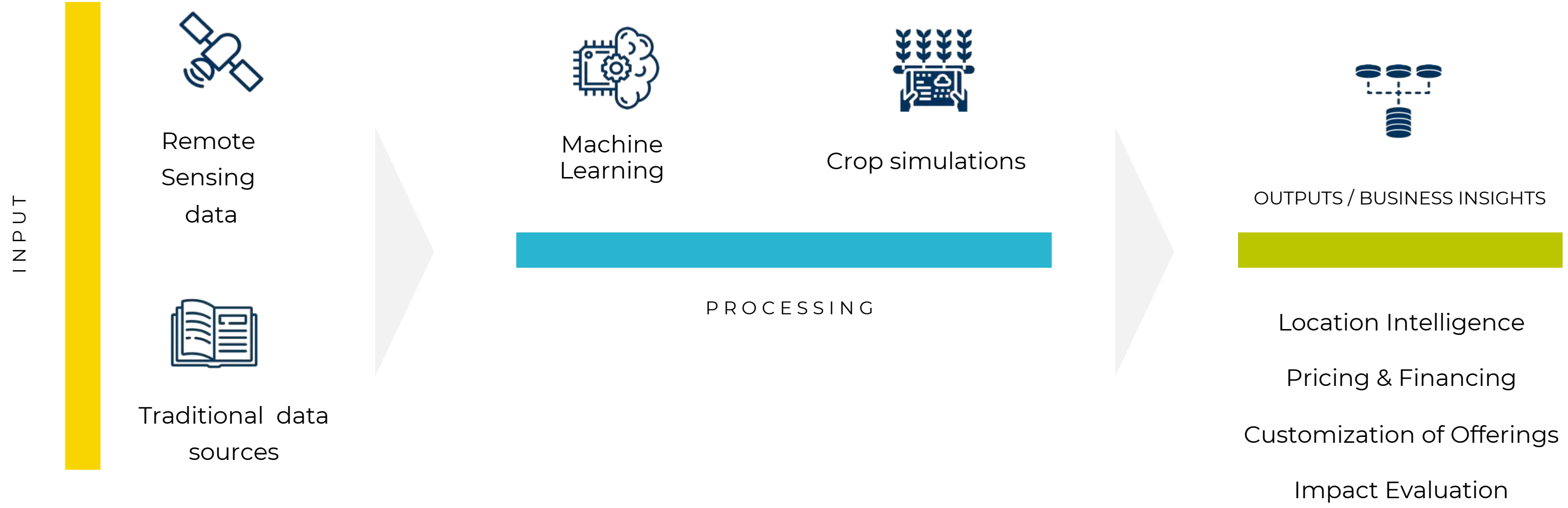
Proposed solution: Creating and distributing information to increase efficiency in the solar irrigation market

The solar irrigation market is information-poor. Interventions that increase the availability of actionable data on the market and consumers have the potential to unlock significant market potential.

In an information poor solar irrigation market…	…providing actionable business insights…	…increases market efficiency.
Clients are dispersed + Value of individual transactions is low + Cost of data collection is high ↓ Buyers' and sellers' have limited ability to estimate return on asset purchase.	Create a scalable database of estimated returns for solar irrigation assets and combined interventions. Leverage the database to create low cost actionable analytics across the value chain.	Scale the market and increase the number of players who offer a diverse and profitable range of solar irrigation products. Make it easier to match consumers with the right products and financing increasing efficiency of customer acquisition and potentially reducing default risks.

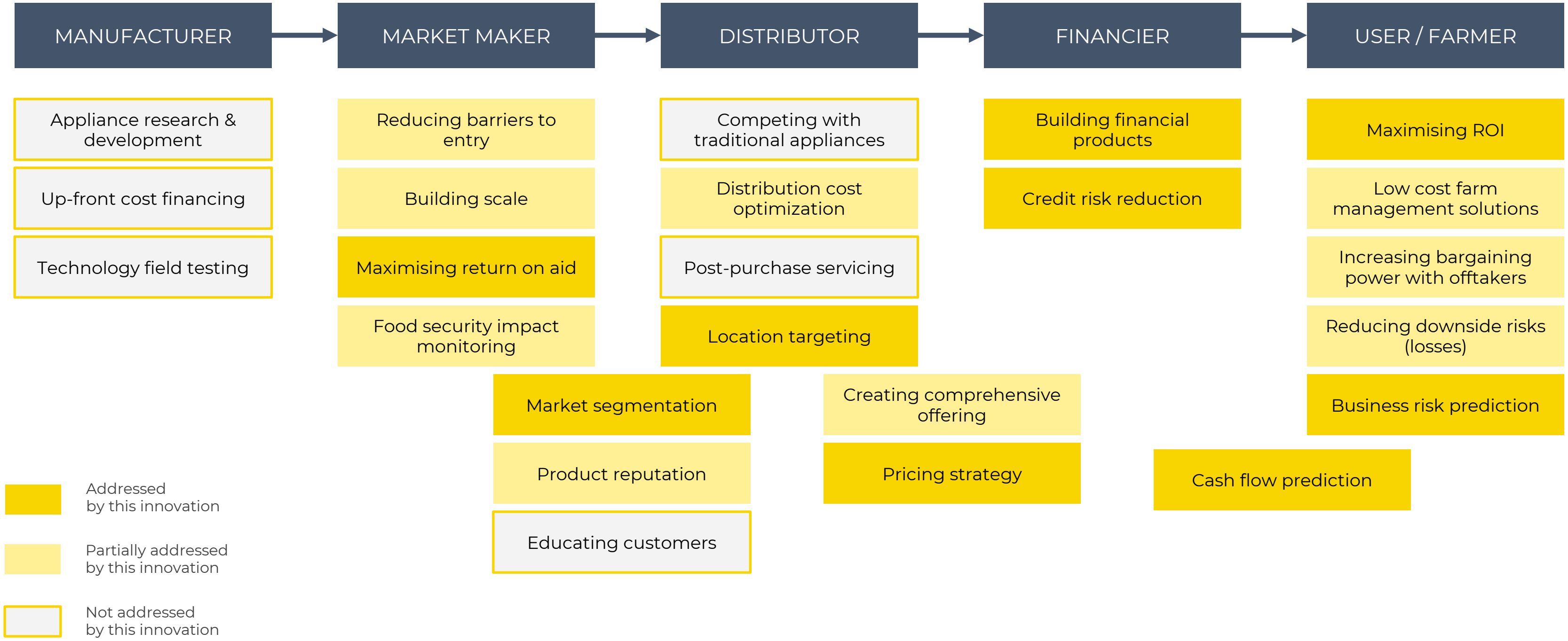
Proposed approach: Combine technological advancements to allow for large scale affordable analysis

We fuse remote sensing data with traditional data sources like survey data, run thousands of crop simulations of individual farms and use machine learning to analyze and predict profitability at scale.



Target users: Derived analysis can be used to inform players across the value chain

Model outputs can be utilized, to varying degrees, by all post-manufacturing value chain actors



Business insight examples: The end goal is to ensure that results are easy to understand and implement

Derived insights can inform all stages of the business cycle

LOCATION

"Farmers in Laikipia have among the highest expected gains on irrigation"

PRICING

"Within a 10 year lifespan the max price an average maize farmer in Eldoret can afford to pay for a SWP is ~200,000 Ksh"

IMPACT

"We see immediate adoption of crop rotation among pump adopters"

PRODUCT

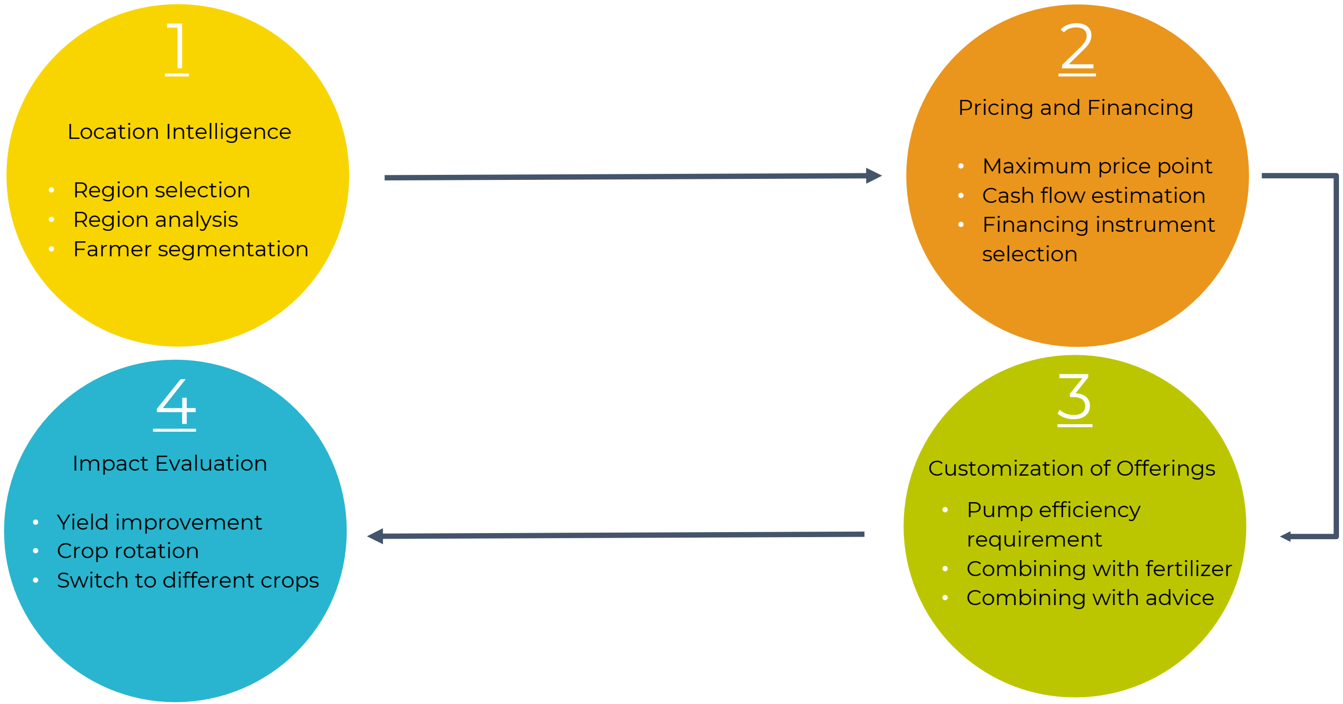
"ROI increases by additional 33% when irrigation is combined with the optimal amount of fertilizer applied in two stages"

CLIMATE RISK

"We expect a near full reduction in losses during severe droughts and extra profit that cover the cost of pump"

Illustrated findings across four example applications

We leverage pilot data from a SWP distributor to show real-life business application of our analysis across four dimensions.



Applications

Location Intelligence

Pricing and Financing

Customization of Offerings

Impact Evaluation

Image credit: Aggrico

We can use remote sensing to create location intelligence for strategic decision making

Remote sensing allows for spatial analysis at different levels of aggregation that can inform strategy at subsequent stages of market entry and development.

It allows sellers and financiers to make systematic decisions when assessing market potential across regions, segmenting potential customers, and devising a location-based sales strategy.

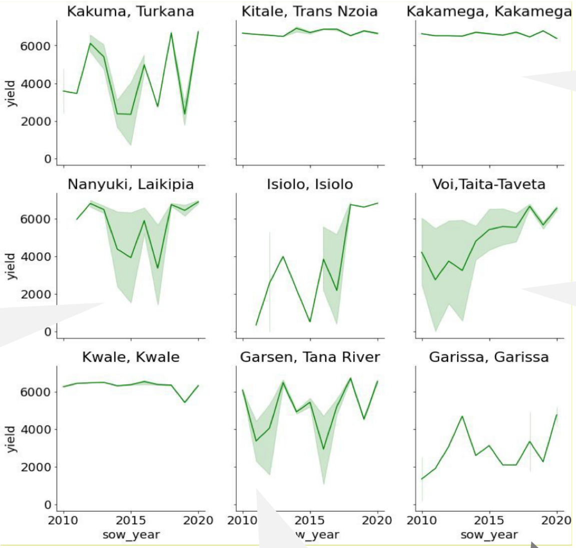
In this section we showcase this by studying nine randomly selected locations in Kenya that represent different physical conditions. For these nine locations, we analyse sales potential and point out differences in sales strategies that this regional diversity requires.

We then zoomed in on a specific location in Western Kenya for which we collected data on the ground. For this location, we show the viability of remote sensing to analyse the level of potential concentration of successful farmers, identify local productivity champions and decide which specific type of pump is most likely to deliver the highest impact in the studied location.

Section summary
Location Intelligence

We can identify regions with high benefits from irrigation

Analysis of potential in nine example regions

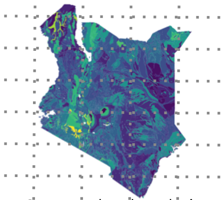


Generally low impact of tested irrigation regimes in wet areas of the country.

High impact of irrigation where the soil is of good quality & rainfall varies .

Confidence bands illustrate the range between the potential yield with and without irrigation.

Impact of irrigation varies in semi-dry parts of the country.



Country- level analysis

DATA NOTE:
The analysis was conducted over small sample areas in the respective regions. More extensive research in geographic as well as parameter space would be required before making strategic decisions.

BACKGROUND INFORMATION

Simulations help us determine where SWPs can be expected to have the largest impact, and how this impact varies over time. Here, we look at the impact in nine example regions in Kenya.

STUDY NOTE

The Sub-Saharan Africa is climatically diverse. Using the example of Kenya, we show how irrigation can have different expected impacts in distinct locations, defined by different weather and soil patterns. For each area, we ran multiple scenario simulations for a range of low-irrigation and high-irrigation regimes.

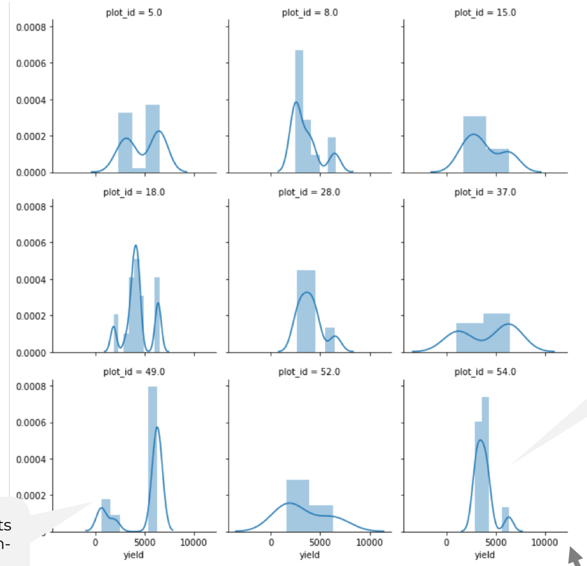
In regions where rains are close to optimal and soils are good (e.g. Kwale), there is no difference in yield between these regimes. The long-term return on irrigation in these regions is expected to be low.

In contrast, in regions where rains are less reliable, but soils are good, such as Nanyuki, optimal irrigation can help achieve constant high yields (upper limit of the shaded area). Without irrigation, a farmer would experience year-on-year volatility.

Garissa is an example of an area that is challenging for farming due to factors other than irrigation, e.g. soil or solar radiation. Here, altering irrigation will have little impact.

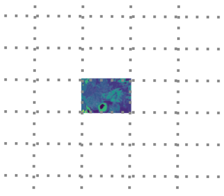
We can assess productivity distributions within a region

Distribution density of potential at different locations



Similar potential across all farmers

Clear two segments of the market: high- and low-potential farmers .



Region- level analysis

DATA NOTE:
The analysis was conducted in sub-regions around sample sites. The range and pivot variable should be modified to reflect the strategic question posed by a specific business or policymaker.

BACKGROUND INFORMATION

In some areas only few, in others almost all farmers would stand to gain a lot from a SWP. By identifying the distribution of potential for SWPs in a region, we can inform sales, communication and intervention strategies.

STUDY NOTE

After identifying an area with high potential gain on irrigation, it is crucial to understand how the potential is distributed among farmers. This metric informs players such as distributors or financiers on whether their client base is dispersed or concentrated.

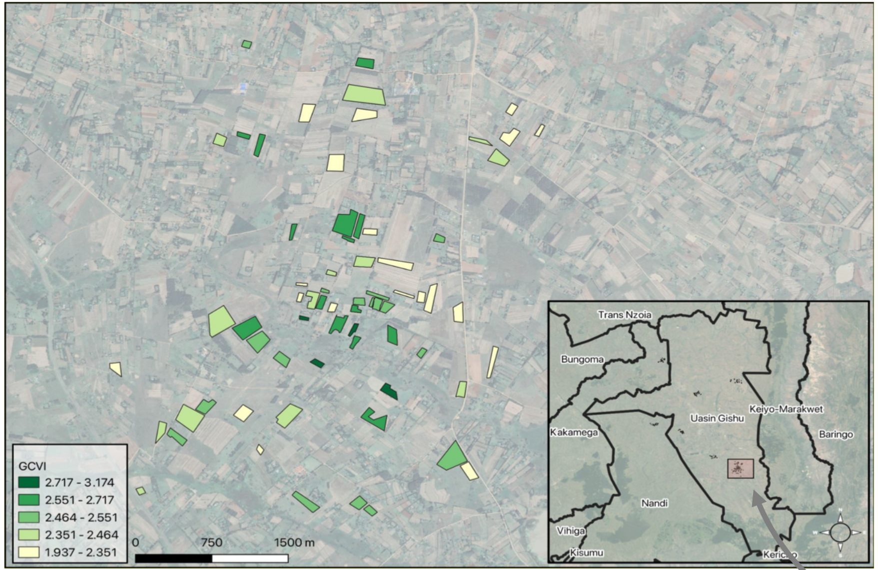
Using data from the pilot, we present distributions for nine locations. Each location represents a community the size of a village located in the western part of Kenya.

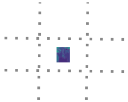
The top-left area surrounding pilot plot number 5 is among the most polarized. About half of the farmers in the community would see a significant gain from irrigation, and almost half would not.

On the other hand, the bottom right graph shows a community where almost all farmers would see a similar gain level, so the distribution of potential is close to unitary.

We can find local champions within a community

Farm-level potential scoring based on customizable indicators





Farm- level analysis

DATA NOTE:
This is an exemplary plot in which scoring was done by computing GCVI maxima over two years, then averaging over time. The metric and averaging should be modified to reflect the concrete question at hand.

BACKGROUND INFORMATION

Farm-level analysis can be leveraged to create inputs into credit scoring models prior to engaging the farmer or even to decide which specific farmers to visit.

STUDY NOTE

High-resolution satellite imagery permits the comparison of individual farm performance with benchmarks in their vicinity. To rank potential customers within an area we can create need-specific scores at the plot level. These rankings should reflect the nature of the assets to be sold as well as the business strategy pursued.

In this example, we zoom into a community that was part of the pilot and rely exclusively rely on satellite data to analyse performance. We created a map with plots that produce higher yields than their neighbours. A SWP seller could consider addressing owners of the plots indicated in dark green first, who are indicated to be more productive farmers and are likely to have resources for new investments.

The green chlorophyll vegetation index (GCVI) used in this example is a measure of canopy greenness observed using satellite imagery that shows high correlation levels with yield.

Applications

Location Intelligence

Pricing and Financing

Customization of Offerings

Impact Evaluation

Image credit: Aggrico

Section summary
Pricing and Financing

By combining remote sensing analysis with crop simulations, we can inform pricing and financing

The value of an irrigation system is most significant for the farmers experiencing the largest yield gaps. Using remote sensing and crop simulations to identify yield gaps at scale, we can uncover the expected value irrigation systems can bring to farmers over a large area. This allows us to estimate price elasticities that we can use for the pricing of SWPs.

Additionally, when we follow yield gaps over time, we can identify risk profiles that require nuanced financing schemes, that are modelled after farmers' fluctuations in cash flow.

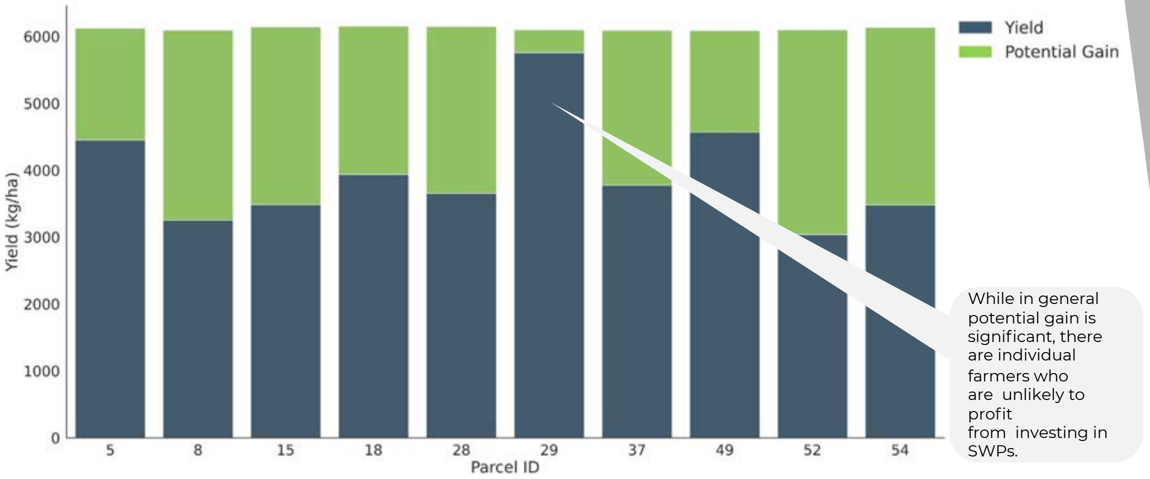
In this section, we showcase the pricing calculations our analysis can inform, based on the example of our pilot plots. We also show how cash flow simulations can help understand and mitigate liquidity risks experienced by farmers investing in SWPs. We conclude that unless financial offerings are tailored to a specific farmers' risk profile and the price elasticity in a region, prices may be suboptimal, and farmers may be unable to take on the risk of credit purchase.

We can determine yield gaps per farm

BACKGROUND INFORMATION

The first step in pricing is to determine the distribution of productivity gains from irrigation, which in turn provides information regarding farmers' price elasticity.

Real yield vs. simulated maximum potential yield had irrigation with fertilization been used



STUDY NOTE

We estimated yields over the period of ten years for ten pilot sites. To do so we correlated approximately 8,000 simulations with observed greenness indices.

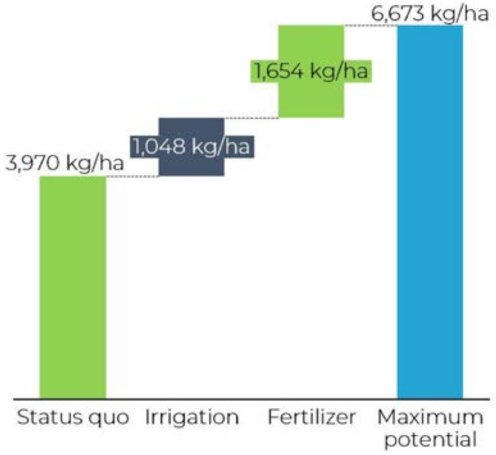
To estimate yield gaps we subtracted observed (real) yield from the simulated maximum yield (potential). For the farms in our pilot the maximum yield stood at 6 tons per hectare. This maximum was estimated for a farmer with an intensive production schedule, who applies the optimal amount of the locally available fertilizer and installs an optimal irrigation system and continues to follow local recommendations for best farming practices.

By testing different irrigation regimes, we were able to estimate the potential yield gain from irrigation at the farm level. The higher the green bar, the higher we estimate the potential gain from SWPs. Interestingly, some farmers in our sample are already close to their maximum potential.

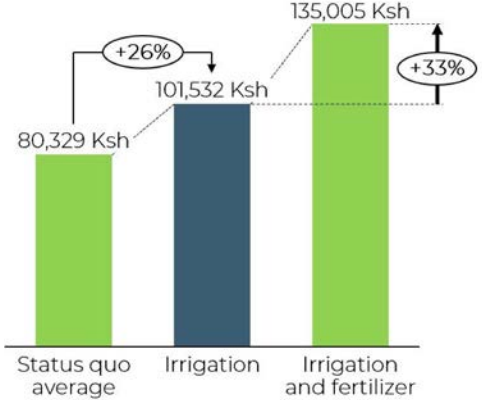
DATA NOTE:
The function that was optimized could be constrained to realistically reflect the range of available inputs, machines and practices. Constraining a function means imposing bounds within which variables can be altered. Using constraints, we can achieve realistic scenarios for a specific machine and a specific context.

We can compute pricing based on yield gaps

Average annual gain in terms of yield per hectare



Average annual potential gain over ten years in Eldoret region - based on average plot size in the study



DATA NOTE:
Like many other interventions, irrigation and fertilization both complement and substitute each other. Hence, the additional gain should not be considered in isolation.

BACKGROUND INFORMATION

The final price for a SWP should be below the expected average gain, but should also take into account the distribution of yield gaps across farmers and competitors' prices in order to maximise total revenue for the distributor.

STUDY NOTE

Our simulations enable us to quantify the additional yield and corresponding monetary value of irrigation, which we showcase here at the example of our pilot plots.

The average gain on irrigation alone in the study area is 26% in monetary terms or approximately a ton of yield per hectare per year. The impact is increased with the addition of fertilization.

Here we show the average impact of irrigation and fertilizer, which we estimate, increases the expected farm income from KES 80,000 to 135,000 per year per hectare.

Before establishing the maximum sales price, the distributor would need to factor in the size of irrigated plot, pumps capacity and lifetime of the pump.

We can tailor financing to reflect variability in yield gaps

Annual average yield gain scenario analysis with and without pump based on actual observed weather conditions in the pilot region

Over a 10-year lifespan of the pump, the average gain for our sampled plots is 1147 kg per hectare per year

DATA NOTE:
All plots in this section are based on our pilot data.

BACKGROUND INFORMATION

Further to knowing the expected gain on the asset, the seller needs to help the buyer mitigate the risk of the gain being below expectation or being realized only in the distant future rather than soon after the purchase.

STUDY NOTE

The pilot region for this study is defined by relatively good natural conditions for maize planting. Predictable and sufficient rains allow farmers to derive high yields even from unirrigated plots.

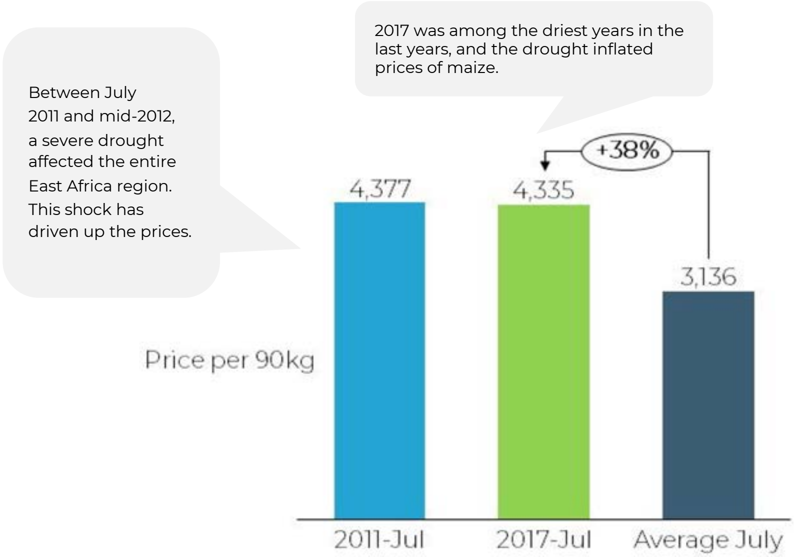
However, during the increasingly frequent drought years, the productivity gain of owning a SWP can be substantial. In the study region almost all the average gain would have been driven by the extra productivity in 2012 – a year Kenya experienced a severe drought.

While gains would have been observed in other years too, without the drought the expected gain a farmer were to derive from the asset would have been much lower.

Therefore, further to establishing the maximum price point the seller needs to consider the likelihood with which the farmer may achieve the expected gain and the time distribution of this gain and design financing schemes accordingly.

When considering variability in yield gaps, we also need to tailor financing to reflect variability in prices

Maize prices in Eldoret during two most severe droughts of the last decade per 90kg bag



DATA NOTE:
All plots in this section are based on our pilot data.

BACKGROUND INFORMATION

Maize is a relatively low margin crop, but for farmers who can supply to the market in dry years, the profit margin may be significant and may justify the purchase of irrigation systems.

STUDY NOTE

Irrigation is very profitable during drought by sustaining yield and allowing to benefit from higher market prices. This graph shows the difference in market prices in normal years compared to dry years.

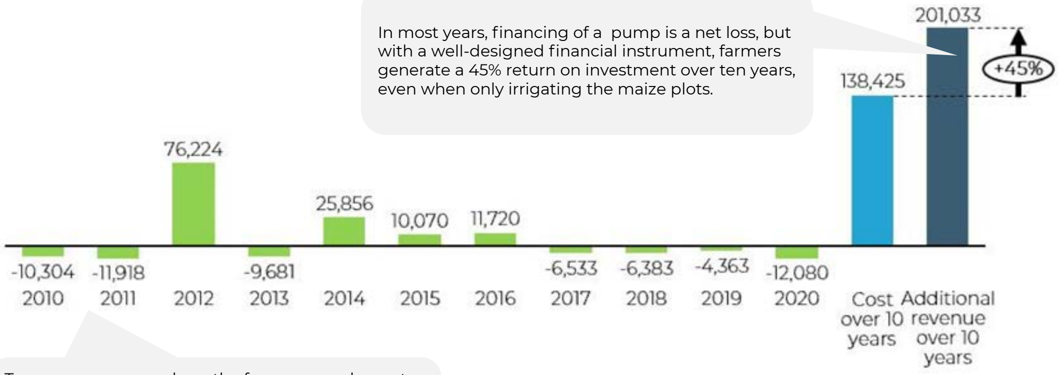
These prices are the reflection of momentarily lower productivity in the country or region. In years with inflated prices, even a relatively modest increase in yield due to irrigation may significantly impact the profit.

The price dynamics illustrated on the graph are a necessary component for estimating the cash flow change that follows the purchase of a solar irrigation system.

Tailored financing should protect buyers from liquidity risk

Cash flow simulated for a ten-year fixed repayment with 15% interest rate on a KES 65,000 irrigation system

In most years, financing of a pump is a net loss, but with a well-designed financial instrument, farmers generate a 45% return on investment over ten years, even when only irrigating the maize plots.



To ensure no years where the farmer records a net loss on the irrigation system ownership, the underlying finance mechanism could incorporate weather insurance, against years when the pump is not in use while payments must be made.

DATA NOTE:
All plots in this section are based on our pilot data.

BACKGROUND INFORMATION

The final step in setting up a payment plan is to ensure that repayments do not jeopardies farmers' liquidity. Short repayment periods commonly seen today expose farmers to large cash flow risks.

STUDY NOTE

Matching the repayment schedule for the asset with the expected cash flow is crucial to address low-liquidity issues among farmers with new and costly technology.

In this plot, we analyzed the impact of a SWP priced at KES 65,000, being used on a one-hectare farm and purchased with a relatively low interest loan of ten years. Significant gains in productivity are only recorded in two out of ten years. The assumed interest and repayment period are more favourable than those currently available to Kenyan farmers.

While this example shows a positive net return, after 10 years, most smallholders purchasing irrigation on credit are likely to experience a negative impact on their immediate cash flow.

Improving financial offerings can mitigate the negative experiences of farmers. It is possible to design a financial product that will maximize the likelihood of repayment, accurately price the financial instrument and ensure that the end-user profits in the long run without going into distress.

Applications

Location Intelligence

Pricing and Financing

Customization of Offerings

Impact Evaluation

We can determine the best customizations of irrigation offerings to realize maximum potential

Combining irrigation with additional inputs and practice changes can multiply its impact on yield. A combined offering, including other goods and services, may result in a higher value product.

For this study, we test the following parameters/ interventions in the area of interest:

- Different levels of fertilizer
- Different planting dates
- Different levels of irrigation

The study area is one where SWPs are currently sold and is characterized by relatively good rains and infrequent dry spells.

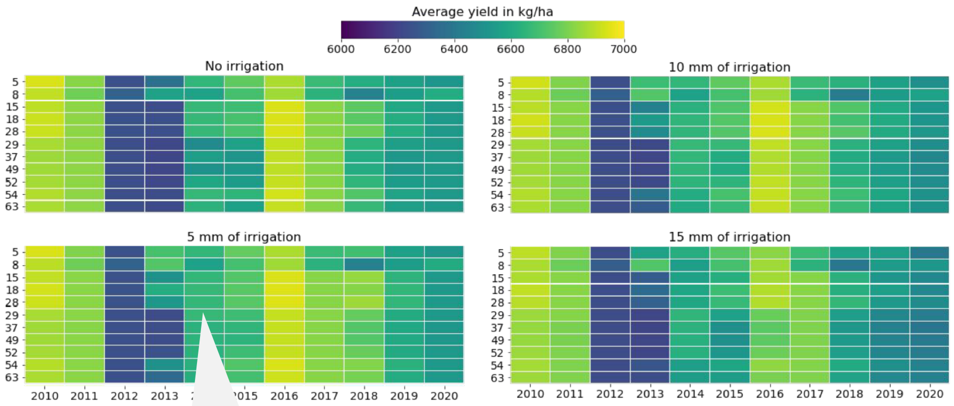
However, in areas like this, the return on irrigation may be lower than in drier areas. Therefore, sellers who want to address this market may benefit from creating combined offerings that include training or additional inputs.

This section shows how agricultural simulations can be employed for customizing the offering and deciding if/which targeted farmers should be offered information on planting practices, soil conservation, or responsible fertilizer use.

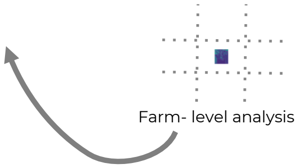
Section summary
Customization of Offerings

We can customize offerings to the needs of a community or a farm

Plot-level impact of different irrigation regimes over ten years



Even low level of irrigation would have protected the yield of plots 5, 8, 15, 18, 28 in the year 2012/2013



DATA NOTE:
All plots in this section are based on our pilot data.

BACKGROUND INFORMATION

Crop simulations allow us to estimate yield performances from many combinations of inputs and farming practices. In this plot we are varying the level of irrigation. In the rest of this section we will study the impact of other inputs that can be combined with an irrigation offering.

STUDY NOTE

This chart shows the 'what-if' scenario for the pilot plots that simulate how much additional yield the farmer can achieve given the local soil and weather conditions.

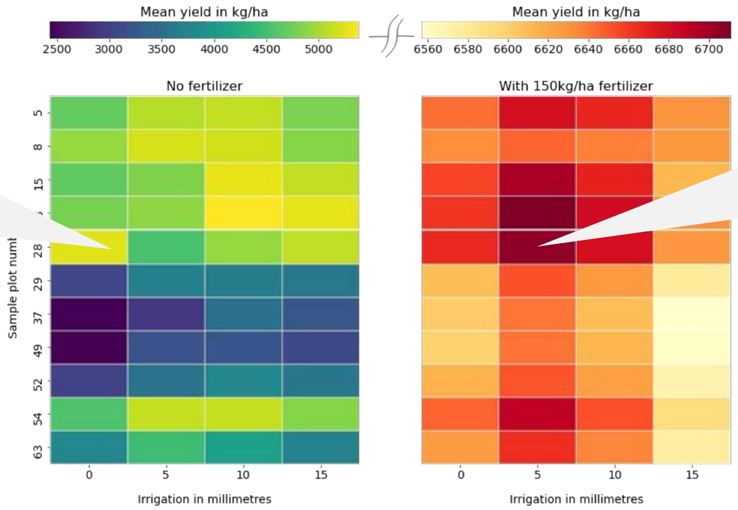
It is essential to model variables such as amount and type of fertilizer, irrigation intensity and planting practices to find the approximate optimal offering that may consist of irrigation, specific inputs and training.

In this example, each box represents a different pump capacity, and each grid row represents an individual plot/parcel from the pilot, simulated over a period of ten years. With this information, a seller or financier of a specific irrigation appliance that is considering a particular farmer or a segment of farmers can understand the expected gain of the client for each asset type and decide on the best offering.

This information helps the seller design the offering for a specific group of clients and decide which of the assets in the offering is suitable for a particular client. The time simulation also informs about the distribution of those gains over the expected lifetime of an asset.

We can estimate the benefit of combining irrigation with other interventions

Expected gain on yield for eleven study plots at different levels of irrigation and fertilization



Up to 30% gains for unfertiliz ed farms from irrigation.

Unlike in the case of unfertilized farms, the sweet spot is with low levels of irrigation that help the distribution of nutrients but do not wash them away.

DATA NOTE:
These analyses apply to a limited number of scenarios for the region in the study. More scenarios over different geographies and for specific irrigation systems could be conducted using the existing analytical pipeline.

BACKGROUND INFORMATION

Without fertilizer application, irrigation has significant effects on increasing yield, even though there is a maximum level of irrigation beyond which it becomes harmful to the crop. When fertilizer is used, irrigation still increases yield, but less so than before.

STUDY NOTE

The impact of irrigation differs starkly depending on whether it is combined with fertilization.

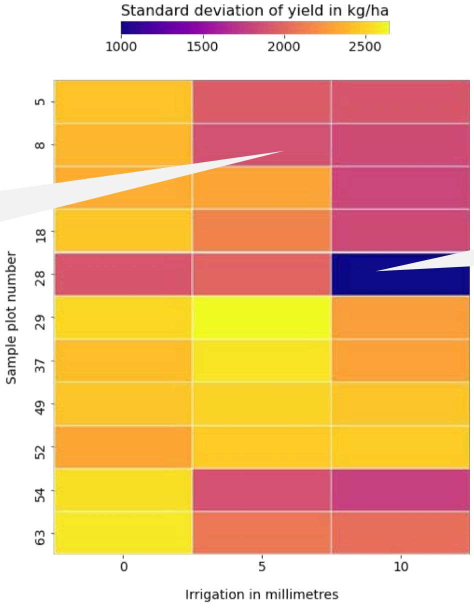
The left panel shows how increasing irrigation (x-axis) impacts yield (the brighter the colour, the higher the yield) for different plots (one per row). Note that this impact is not linear or uniform.

The right panel shows the impact of increasing irrigation when also using fertilizer (the darker the colour, the higher the yield). The optimum irrigation decreases when coupled with fertilizer.

However, a well-managed irrigation schedule may help reduce reliance on fertilizer and still allow farmers to successfully reduce the yield gap while ensuring that the soil remains healthy.

We can customize marketing materials based on specific benefits identified, example: stability

Standard deviation across years with different levels of irrigation based on pilot plots



Even small amounts of irrigation allow for a reduction in standard deviation and improve the predictability of the harvest.

Significant reduction in standard deviation for irrigated farms.

DATA NOTE:
These analyses apply to a limited number of scenarios for the region in the study. More scenarios over different geographies and for specific irrigation systems could be conducted using the existing analytical pipeline.

BACKGROUND INFORMATION

Irrigation reduces variability of yield allowing farmers to enter into profitable long-term contracts. Farmers who can better foresee their yield may get better prices from off-takers. This information could be included in the marketing materials for SWPs.

STUDY NOTE

This plot shows how increasing irrigation (x-axis) impacts yield variability as measured by the standard deviation of yield between years (lower standard deviation corresponds to darker colours).

Lower variability is an advantage for farmers as it improves planning and smoothes cash flows.

Farmers who can commit to delivering a certain amount of crop with a high degree of confidence build a reputation and therefore sell to more professional off-takers while enjoying more bargaining power and enter into long-term contracts that reduce their reliance on middle-man.

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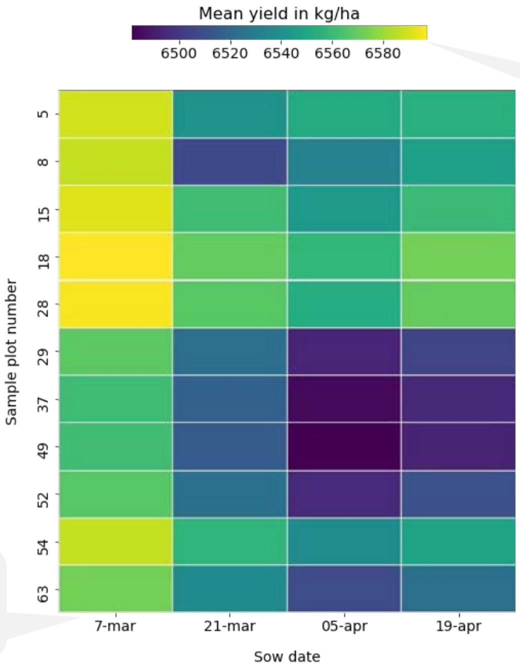
We can customize marketing materials based on specific benefits identified, example: timing of planting

Impact of alternating the sowing date for irrigated plots



Low variation, differing by at most 120 kg/ha.

Planting date can be moved by as much as 6 weeks without a significant impact on yield.

DATA NOTE:
These analyses apply to a limited number of scenarios for the region in the study. More scenarios over different geographies and for specific irrigation systems could be conducted using the existing analytical pipeline.

BACKGROUND INFORMATION

Intensification of farming through optimal irrigation and fertilization allows farmers to choose the planting/harvesting date with the freedom to target higher market prices. This information could be included in the marketing materials for SWPs.

STUDY NOTE

This plot shows how changing the planting date impacts average yield (the higher, the brighter) for different locations (one per row).

In this example, we see that, when irrigation is available, earlier sow dates yield slightly higher yields for the regions under study. However, with good use of irrigation and fertilization, the difference is minimal. Allowing farmers to effectively choose their planning data rather than rely on harder to plan, yet commonly used in Kenya, rule-of-thumb formulas advising to plant within a specific period after the onset of rains.

Applications

- Location Intelligence
- Pricing and Financing
- Customization of Offerings
- **Impact Evaluation**

We show how to monitor the impact SWPs have on farmers who purchased them

Both businesses and development partners need to ensure that users of their products benefit from the purchase. Using remote sensing and crop simulations, we identified the following impacts for our pilot plots:

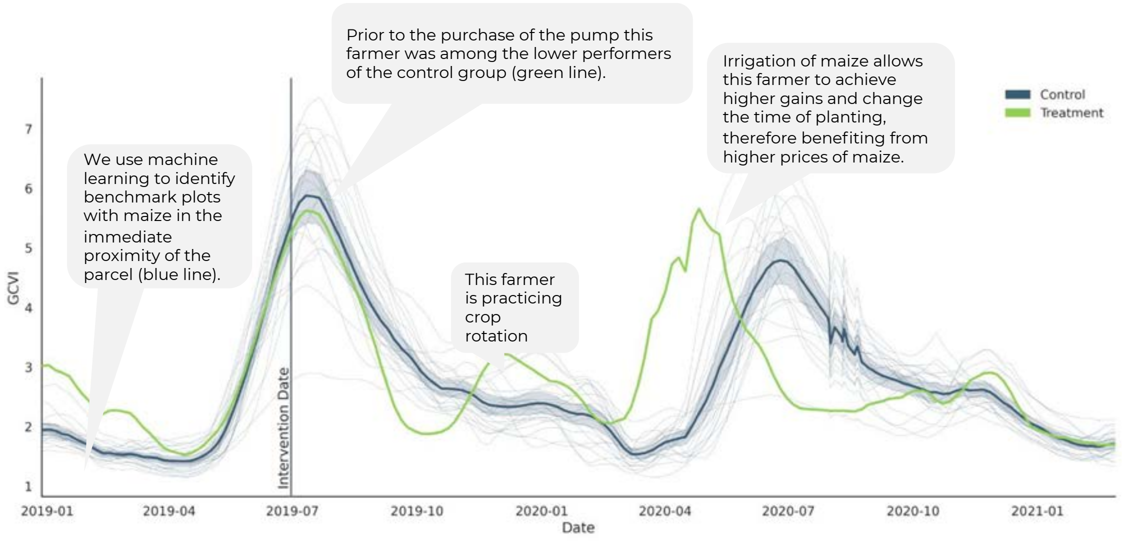
- Higher yield
- Ability to adjust the planting season to increase profit
- Introduction of crop rotation
- Moving away from maize towards more productive crops

In the following slides, we present visual examples of these impacts for the pilot plots. Benchmarking was done using the nearest neighbor algorithm to identify nearby maize farmers based on their initial similarity to pilot plots.

Our analysis focuses on maize but would benefit from extension to other crops farmed by farmers who purchased SWPs. The true power of the analysis becomes apparent when conducted over a larger sample and interpreted by a trained algorithm.

We can identify farming practices before and after the purchase of a SWP

Plot of the greenness level for a farmer who purchased a SWP and for his automatically selected reference group



DATA NOTE:
To study the impact of the purchase of a SWP, we follow the development of vegetation indices over the irrigated area to estimate realized yields vis-a-vis benchmark plots that are not irrigated. Currently, only maize is algorithmically interpreted. For the complete picture, all main crops cultivated in a given region should be added.

BACKGROUND INFORMATION

Because remote sensing data is available across the globe and several years into the past, we can study characteristics of those who buy a SWP and the impact of irrigation without a baseline study, in a coherent and automated way.

STUDY NOTE

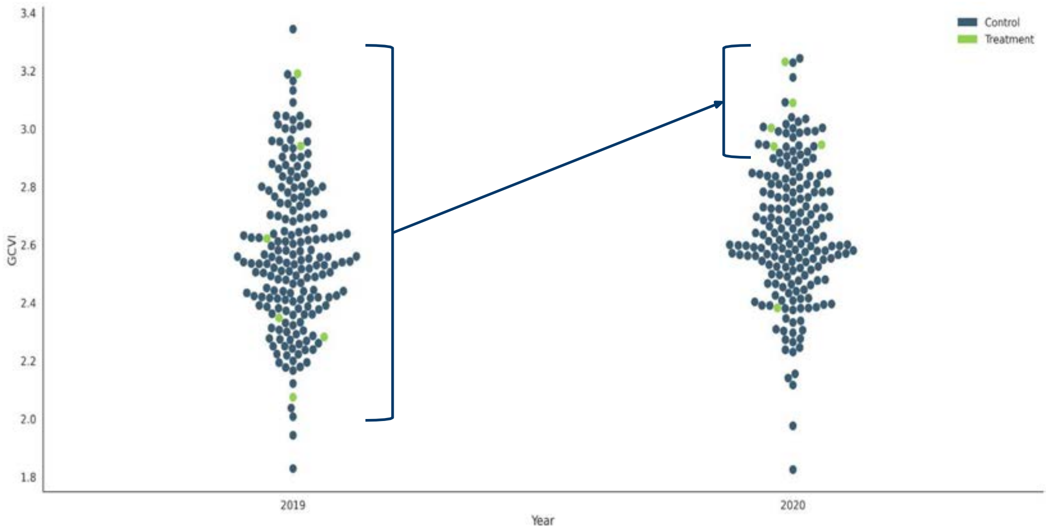
This study proposes a method to monitor the impact of SWP on users by comparing them to an automatically pre-selected reference group specific to each of the clients. This makes it possible to ensure that the observed impact is due to the new investment and not to external changes.

Since the impact is monitored remotely and in real-time, SWP sellers can conveniently update their strategy if end users do not realize the expected benefits. Either by providing new services, such as information on using the asset more effectively or by changing the sales strategy to address specific user segments.

In this graph, the green line is the vegetation index of a plot of a farmer that purchased a SWP, and in grey are benchmark plots. The average benchmark and the standard deviation are indicated by dark blue and grey shading, respectively. In this case, the farmer who owns a SWP is one of few to practice crop rotation and has substantial yields, likely enabled by the SWP.

We can benchmark farmers pre and post intervention even without a baseline study

Treated sample vs. 183 reference plots pre- and post- introduction of SWP



DATA NOTE:
While our small sample of farmers with SWPs allows only for anecdotal data, we see a clear increase in performance vs reference group.

BACKGROUND INFORMATION

Machine learning allows us to quickly identify reference plots as a benchmark for farmers that purchased SWPs. Comparable benchmarks enable us to evaluate the impact of the SWP intervention and make judgements of their statistical significance.

STUDY NOTE

The field testing for this project only allows for anecdotal evidence, but when we look at yield distributions pre-and post-purchase of SWPs, we see that the group that purchased SWPs improves yields as proxied by vegetation indices.

In 2019, the future SWP customers' proxied yield was evenly dispersed among the reference group. In 2020, nearly all farmers who purchased a SWP performed in the top quantile of farmers.

Key applications and next steps

Proving the applicability of this model is the first step

KEY APPLICATIONS

- Identifying locations where a subsidy for an asset such as a solar water pump would be most effective in raising farm incomes and finding areas most vulnerable to climate change and natural disasters.
- Improving risk assessments and reduce the cost of credit scoring based on the estimated yield and cash flows
- Developing customized offerings for farmers including bundling products with extension services and sustainable irrigation equipment.
- Impact evaluation on yield improvement and new farming practices such as crop rotation/intercropping.

NEXT STEPS

- Enrich the model through additional data on actual irrigation levels/pump utilization, fertilizer application and other farming practices that affect crop yield.
- Expand the scope of the model beyond Kenya and beyond the maize crop.
- Incorporate model in a SWP financing program to inform smart allocation of solar water pumps.

Got any questions?

GET IN TOUCH:

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Appendix

Methodology

Background Analyses

ANALYTICAL PROCESS

1

A lengthy data fusion exercise where we collect data on the physical environment of farms and farming practices.

DATA FUSION

2

Simulations of all possible realizations of several crop cycles. We do this for all farms in our area of interest. These simulations provide distributions of potential farming outcomes for every grid cell in this area.

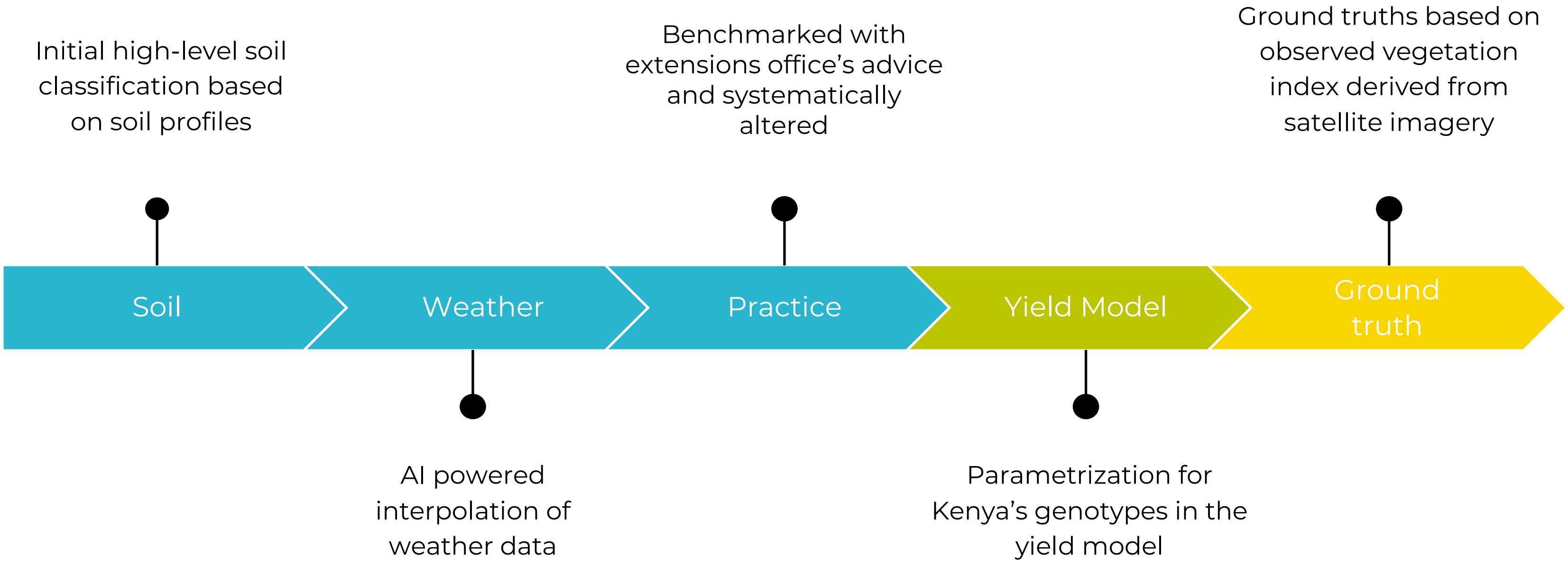
SIMULATIONS

3

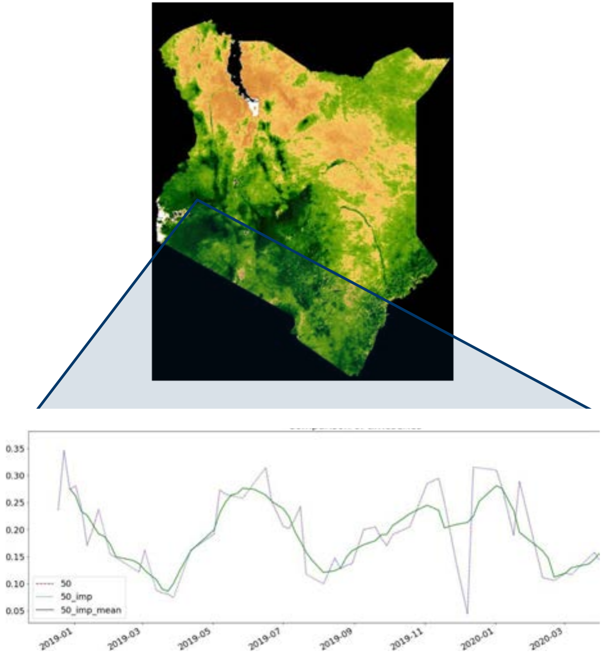
Overlaying simulated realizations with the observations we obtain from high-resolution satellite imagery to understand how real yields compare to potential yields, and what the causes are.

SATELLITE IMAGERY

STEPS OF ANALYSIS



SCHEMATIC OF THE PROCESS



We match observed satellite imagery derived profiles with simulations.

We clean data derived from satellite imagery and compute a vegetation time series. These computed time series are then matched with simulation profiles.

Satellite derived imagery informs what is happening on the ground.

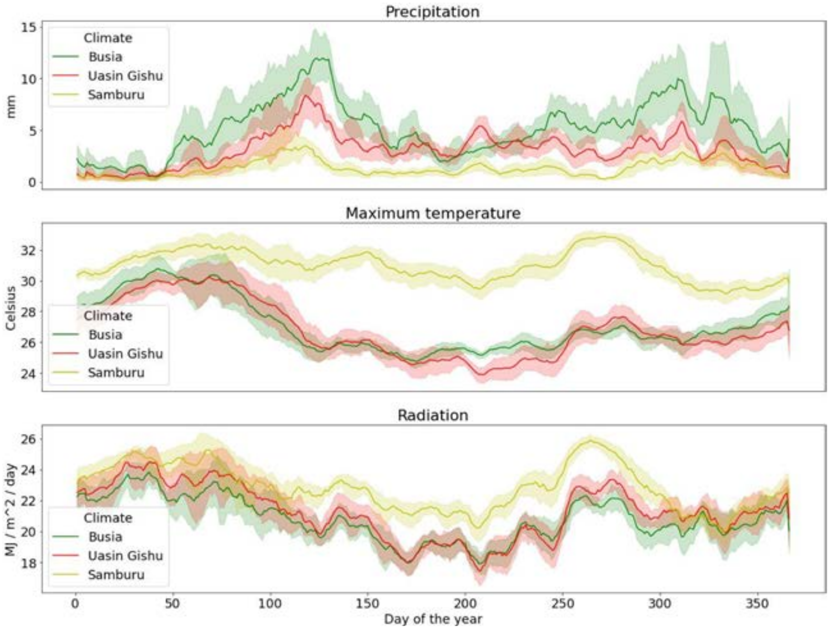
There are several reasons why a specific farm sees realizations below potential. For example, they may depend on farming practices or localized factors such as soil erosion. Comparing satellite derived vegetation time series with simulated time series, we can identify the most likely combination of inputs and farming practices used.

Appendix

Methodology

Background Analyses

Segmentation by physical condition



Climate, weather and soil data is very useful for initial segmentation of the SWP market.

We identify the areas with the highest climatic and physical potential. All analyses are conducted per high-resolution grid element and allow multidimensional segmentation.

- Mapping over standardized soil profiles and derived water properties
- Leveraging AI interpolated high-density virtual weather stations
- Factoring in solar radiation to estimate the real working time of solar appliances and optimize energy storage requirements

Pilot

We conducted a pilot to verify results from the model and anchor them in a real setting.

Images taken in the pilot locations show the variety of crops grown and their stages of development at the time of interview.

0.6244602, 35.2463479

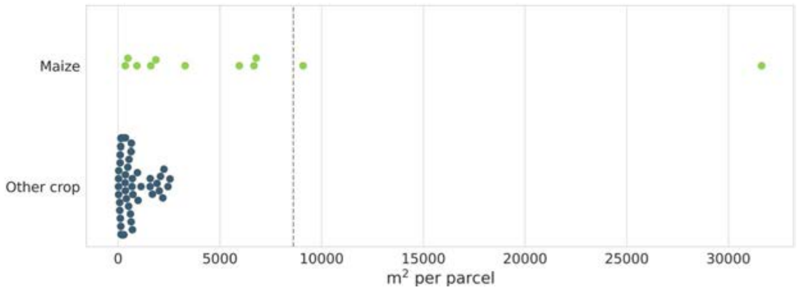
0.6701484, 35.3861346

0.6700583, 35.3857784

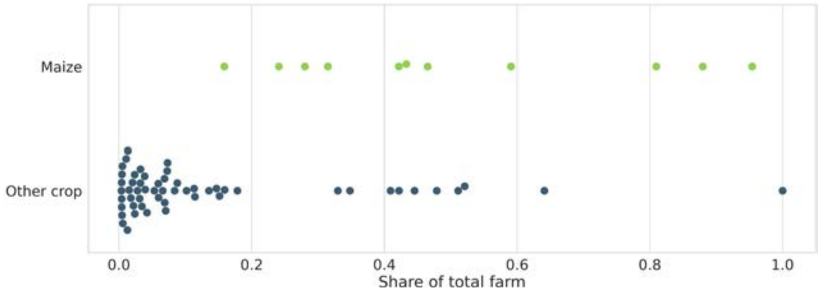
0.4666717, 35.0491

Pilot

Size of parcels in the study



Maize plots as a proportion of total plots owned by a farmer



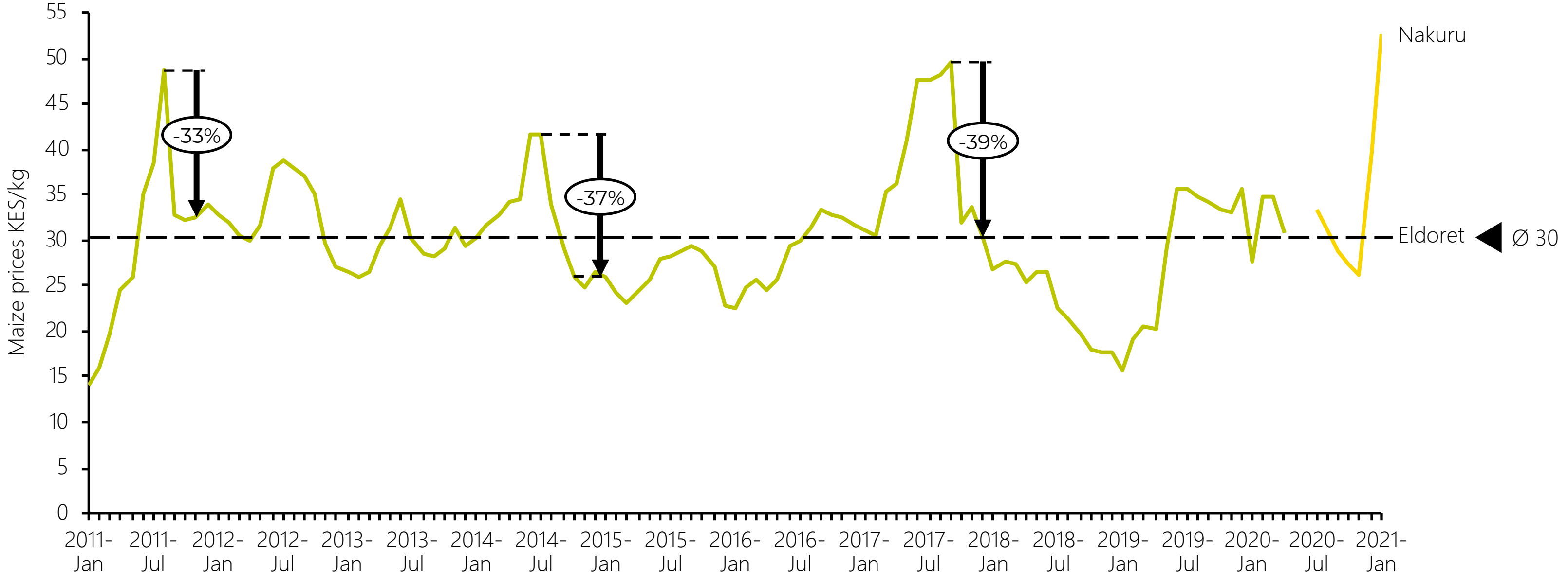
Parcel sizes of farmers in our pilot were representative of the typical smallholder in Kenya

We used a small sample (6) of maize farmers who recently purchased a SWP and irrigate their maize plots. We then matched them with 183 auxiliary, algorithmically identified plots to serve as a control group.

The intervention plots were relatively small, with the average size of 0.7 hectares (1st graph). Maize plots constituted the main crop by area for studied farmers (2nd graph).

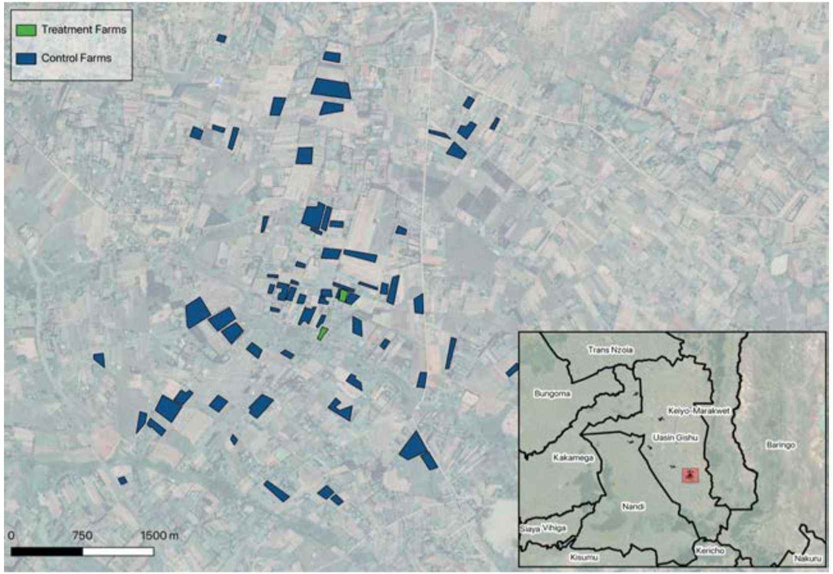
Monthly maize price dynamics in Eldoret/Nakuru

The maize prices we used for cash flow calculations with indicated high within-year variations



Source: www.mfarm.co.ke

Identifying auxiliary maize farms



We built a robust control group to enable impact evaluation

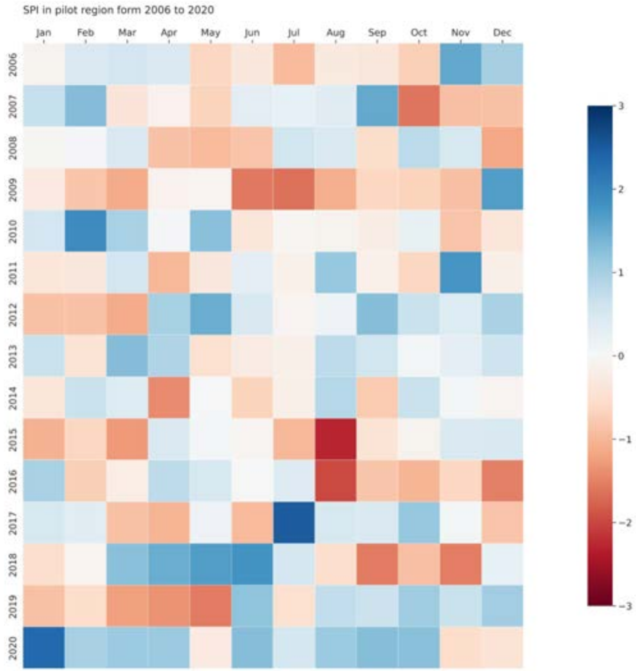
We identified several auxiliary maize farms for each pilot participant using the nearest neighbour algorithm and leveraging the distinct crop storing pattern of maize used in the region.

Index to characterize meteorological drought

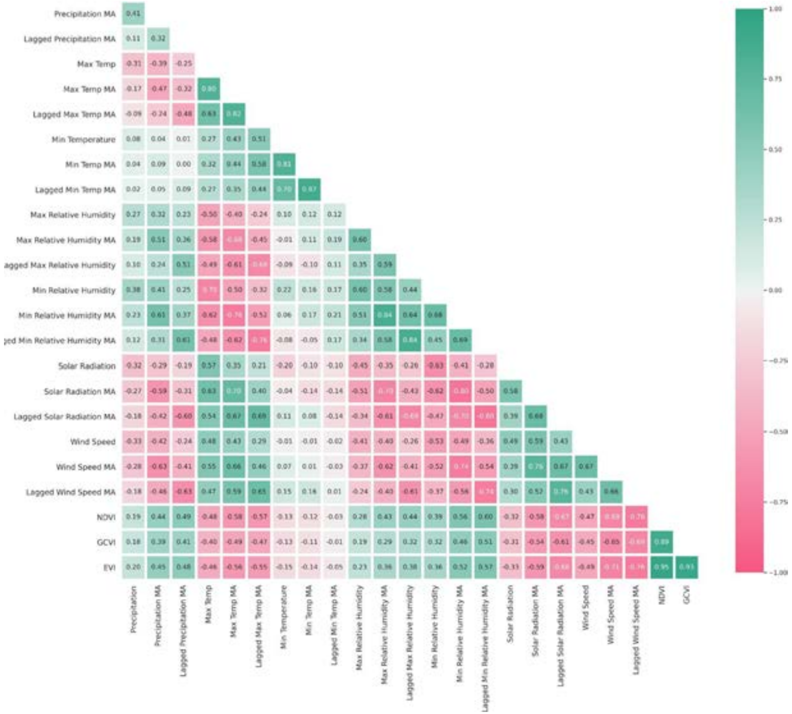
Standardized Precipitation Index (spatio-temporal mean) in the pilot region

The SPI is a useful tool to objectively assess dry and wet periods against the 'normal' for the region and can be used to calibrate financial instruments to weather patterns.

SPI value	Category
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Normal
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 and less	Extreme drought



Weather drivers of yield - correlation matrix



Additional value can be generated by exploring relationship between the variables in the dataset we built for the analysis

We observe a clear relationship between weather and crop performance that enable us to forecast and act.

Lagged weather variables.

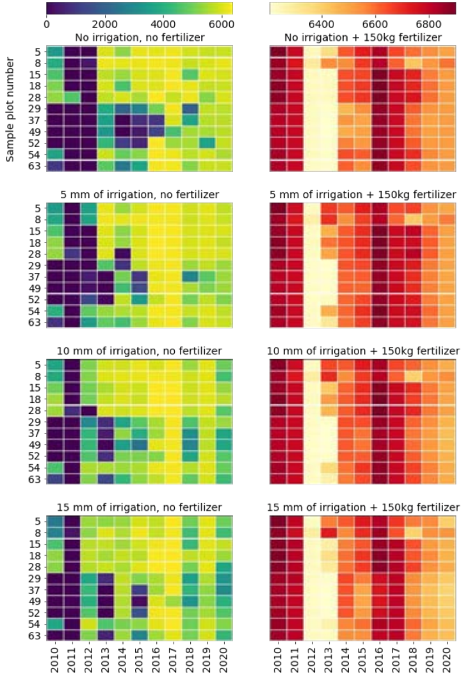
Using these, we can forecast performance and provide early market signals that enable supply chains to pre-empt adverse events.

Negative vs positive impact variables.

The direction and strength of correlation enable us to identify weather phenomena that present challenges in specific regions and assess whether the market addresses these adequately.

Mean estimated yield for plots in the sample

Expected gain on yield for 11 study plots at different levels of irrigation and fertilization, by plot.



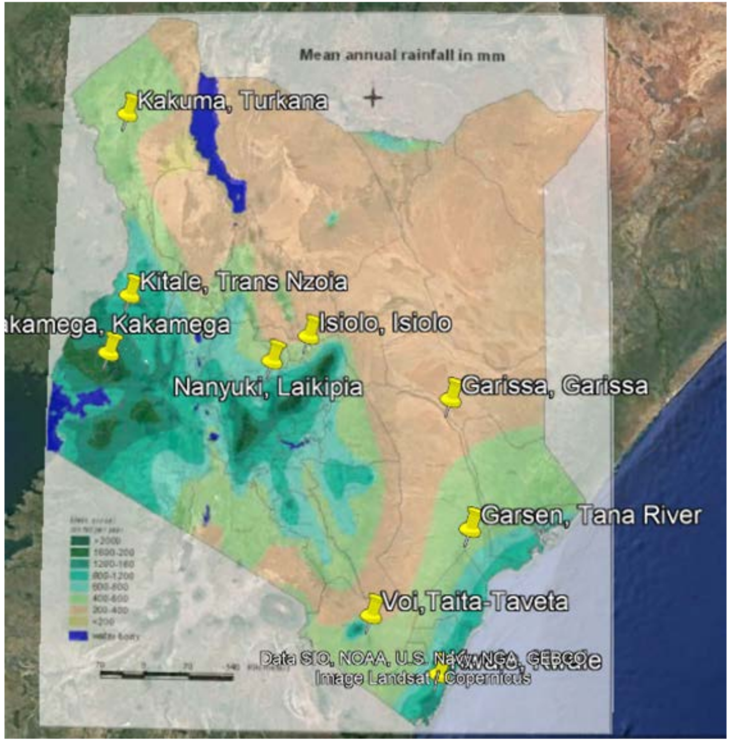
We can study performance at plot level and understand anomalies by assessing the underlying soil and weather patterns.

In our sample, we find a considerable heterogeneity of expected crop outcomes, particularly without fertilization. Suggesting that fertilizer is a crucial equalizer to overcome differences in soil quality.

Irrigation helps unlock additional gains of fertilizer, but it can also act as insurance: it raises yields significantly in the absence of rain and fertilizer.

To best serve the market, it is crucial to factor in this heterogeneity in designing irrigation offerings and tailoring them by region and/or farmer.

General classification of regions by rainfall



Using rainfall maps, we can identify regions to study in more detail.

About RTLAB

The company

Founded in 2018, RTLAB combines expertise in economics and data science to build products and provide advice informing the development of agricultural markets in low- and middle-income countries.

Our strength lies in leveraging remote sensing and agricultural systems modelling to generate actionable market insights that allow policy makers, market actors and market development stakeholders to improve the efficiency of agricultural markets.

We focus on innovation projects leveraging academic research and recent technological advances.

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