FINAL REPORT

ThirdEye Kenya: Flying Sensors to Support Farmers' Decision Making

REPORT 192

CLIENT **SNV**

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Summary

In November 2017 HiView and FutureWater (The Netherlands) set up the ThirdEye flying sensor (drone) service as part of the Smart Water for Agriculture (SWA) project, implemented by SNV, funded by the Embassy of the Netherlands in Kenya. This final project report gives an overview of the activities undertaken over the past two years and presents the results achieved.

ThirdEye's operators are equipped with flying sensors, tools to analyse the obtained imagery and knowledge to give valuable advice to improve farming practices. Apart from this, ThirdEye is offering other services such as training, soil testing and input supply, far beyond the border of Meru County alone.

Over the past two years ThirdEye was officially registered as company in Kenya, a company office was opened at Kaguru ATC, the team has grown to eight professionally trained flying sensor operators, thousands of paying farmers have adopted the service, partnerships were formed with many stakeholders in the value chain (e.g. Soil Cares and Lentera Africa), the service was featured on national television and many field campaigns have taken place. A total of 9607 persons were positively affected by the service, which was provided on a total area of 4217 acres (1707 ha).

A water productivity analysis using satellite data in combination with an algorithm for estimating water productivity, showed an increase of 20% in ThirdEye areas compared to control areas. Since most of ThirdEye's advisories were about boosting soil nutrients or diminishing pests, this increase is mostly caused by an increase in crop production and not by a decrease in irrigation water usage. Therefore, the total yield increase as a result of the service was considered to be 20% as well, which equals 7.3 tonnes. If these crops would have been grown on traditional farmland (i.e. without ThirdEye services) 341.3 ha would be needed (478 football fields).

The increase in crop production also lead to an equal increase in revenue. The total increase in income thanks to the ThirdEye service equals more than 79 million KES (667,910 euro). Per farmer the revenue increase comes down to 38.7k KES (327 euro). These numbers were affirmed by several farmers who received the service, which are described in the success stories in this report.

At this moment, ThirdEye is in last phase of the transition from a project to a commercially viable Kenyan service provider, meaning sustainability is ensured, a train-the-trainer system is in place and geographic expansion is possible. Total sales have reached KES 733,875 so far and a return-on-investment analysis shows that investment viability is reached within a timeframe of 7.5 years from now for the medium revenue scenario (RoI after 10 years of 23%) and within 5.5 years for the highest scenario (RoI after 10 years of 83%).

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1 Introduction

A key factor in enabling more efficient and increased food production is providing farmers with relevant information. Such information is needed as farmers have limited resources, such as seeds, water, fertilizer, pesticides and labour, and are hindered in their access to information sources. Spatial information from ThirdEye's flying sensors (drones) can be used for this. Our low-cost flying sensors have cameras which can measure the reflection of near-infrared light, as well as visible red light. These two parameters are combined with a formula, giving the Normalized Difference Vegetation Index (NDVI). This information is delivered at a resolution of 2x2 cm in the infra-red spectrum. Infra-red is not visible to the human eye but provides information on the status of the crop about 10-days earlier than what can be seen by the red-green-blue spectrum that is visible to the human eye.

Our innovation is a major transformation in farmers' decision making regarding the application of limited resources such as water, seeds, fertilizer and labour. Instead of relying on common-sense management, farmers are now able to take decisions based on facts, resulting in an increase in water productivity. The flying sensor information helps farmers to see when and where they should apply their limited resources. We are convinced that this innovation is game-changing, comparable with the introduction of mobile phones that empowered farmers with instantaneous information regarding markets and market prices. With information from flying sensors they can also manage their inputs to maximize yields, and simultaneously reduce unnecessary waste of resources. In summary, the missing information on markets has been solved by the mobile phone introduction, the flying sensors close the missing link to agronomic information on where to do what and when.

The ThirdEye service was set up by HiView and FutureWater (The Netherlands) in Meru in November 2017 as part of the Smart Water for Agriculture (SWA) project, implemented by SNV, funded by the Embassy of the Netherlands in Kenya. This final project report gives an overview of the activities undertaken over the past two years and presents the results achieved.

2 ThirdEye team

2.1 Local manager

Hiring a local manager for the ThirdEye service in Meru was the most important first step to be taken. After having conducted several job interviews Faustine Kiogora Julius (Kiogora) was hired. To date, Kiogora is ThirdEye Kenya's general manager and sole owner of the local company.

Figure 1. Local manager Faustine Kiogora Julius.

Aged 27, Kiogora is living in the lively city of Nkubu, close to the ThirdEye office at Kaguru ATC. He is a graduate from the University of Eldoret, having obtained his BSc in Agricultural Economics. As a child, Kiogora was already very much into agriculture because his parents had their own farm and he could see them generate a lot of income from the selling of their produce. "Everybody needs to eat and that really attracted me toward agriculture. I have seen major changes in farming over the past years, which have interested me even more to explore it much deeper", according to Kiogora. After his studies, he engaged in companies that are related to agriculture, in particular by using innovative technologies. These companies have changed his mind set: "I really think that state-of-the-art technologies can benefit farmers." For years Kiogora has been transmitting this message to farmers and now, as owner and general manager of ThirdEye Kenya Ltd., he is even more dedicated to help farmers improve their productivity with the use of flying sensors. "The combination of flying sensors, soil testing and in-field extension service really benefits farmers. Together we boost their productivity and income."

2.2 Operating team

During the first year of the project the first part of the team was formed: one local manager, Kiogora Faustine Julius, and give (flying sensor) operators: Veronicah Nyaguthii, Vyonne Mukami, Ian Mwirigi, Fridah Kagwiria and William Mithika. In the second year additional operators were added to team after an intense training by current operators and flight operations manager Jan van Til. Benson Mwaura, Bernard Muriithi and Purity Kinya were added to the same. Also, a sales manager was hired: Simon Ngari.

Figure 2. The ThirdEye team in Meru, Kenya.

Now, at the end of the funding period, the whole team is still active, all working full time, except Simon Ngari and Ian Mwirigi, who left the company. ThirdEye's operators are equipped with flying sensors, tools to analyze the obtained imagery and knowledge to give valuable advice to improve farming practices. Every Wednesday morning the team meets for an extensive team meeting at the ThirdEye office in Nkubu.

2.3 Support staff

This local team is supported by Martijn de Klerk from FutureWater and Jan van Til from HiView in the Netherlands with regular skype calls and visits to the office in Nkubu.

Figure 3. Jan and Martijn in the tea fields in Marimba, Meru County, Kenya.

3 Highlighted activities

3.1 Office set-up and company registration

Since early March 2018 we established our own ThirdEye office at the premises of the Kaguru Agricultural Training Centre in Nkubu. The office is used to have (remote) team meetings, process images on the new desktop computer, make prints of PR material, invite partners and receive clients. Having this office as base for our activities has been of extreme importance over the past months, not only for the bonding of our operating team, but also for the visibility towards our partners and clients.

Figure 4. The ThirdEye office in Nkubu.

In May 2018 ThirdEye was registered as official limited liability company in Kenya. This was needed in order to be able to pay out wages to our operators and to set-up a bank and M-Pesa account. All documents related to the registration of the ThirdEye company can be found in Appendix 1.

The company registration was used to open a bank account in June. The account is used to gather all M-Pesa transactions from clients, to pay the operators on a commission basis and to save money for future investments. Early July our M-Pesa account was also opened, with till number 522522. Farmers have already started paying to this new account, which is used by almost every farmer.

3.2 Technical refinements

ThirdEye Kenya has gone through a rapid development during the second year in which it has received SWA support. This mainly concerns the cameras and the flying platforms itself. But also, in the perevery technical improvements and adaptations are on-going. Some of the improvements have been implemented, other are still underway to be operational.

In this section we give an update of the technical developments, starting with its main component, the operational equipment. After that a short description is given of our innovations in image processing. The full details of the technical refinements can be found in a separate report (ThirdEye Kenya – Technical Refinements Report, HiView Report, October 2019).

3.2.1 Cameras

Improvements were achieved by fine tuning the settings of the RGB camera. By testing several settings could be improved:

- Exposure time is now being regulated and is not to exceed 1/500 sec.
- ISO must be adapted to 50 (from 100) in very sunny conditions
- For the sake of avoiding saturated color values these values should remain under the threshold of 255.

The commonly used NIR camera is the GoPro Heron 4, black edition. This camera is mounted on a mount that was designed by HiView. Commonly the mount is fixed by screws. A novel method was invented by HiView to fix the moint using tie-ribs. Although the screwing method is preferred the tie-ribs methods has the advantage of easily taking of the mount. This might be needed in cases that the Mavic will be transported. The ThirdEye operators are able to mount the GoPro camera using the tie-rib method (Figure 5).

Figure 5. Mavic 2 with tie ribbed mount.

Much time was spent by orientating on an alternative NIR camera. The actually used GoPro camera is still functioning fine, but there are some reasons to look for its replacer. It is getting harder to order the GoPro Heron 4 because its production has been discontinued since some time. Another disadvantage of the GoPro is that is not integrated with Mavic UAV. Finally, we found a good successor: The MAPIR Survey three. The most important improvements are:

- GPS tracking. A GPS device is connected to the MAPIR camera and stamps the NIR images with geo location information. Otherwisely put the MAPIR images are geotagged. This is shortening the processing time of the NIR images, as manually georeferencing becomes superfluous.
- Calibrating the NIR images. A reflectance panel is used to calibrate the color values, thus improving the NDVI values.
- Mount. The MAPIR camera is supplied with a Mavic specific mount
- Costs. The costs of the MAPIR camera and reflectance panel (€ 750) are very moderate as compared to similar cameras that are on the market, like the Sentera camera, the Sequioa from Parrot amongst others. HiView and FutureWater have put a lot a energy to finally find the best camera fit for the ThirdEye operations.

Figure 6. Mavic PRO with Mapir cam and GPS mounted.

One of the major developments concerning the UAV sensors is the IR (InfraRed) camera, also named thermal camera. Measuring soil and plant temperature, the evapotranspiration (ET) can be calculated. Crop temperature and ET are means to indicate crop stress that is specifically related to water. The WSVI index is used for mapping crops and showing zones with water related crop condition values.

Similar to the NDVI mapping, zones can be indicated of crops that are suffering water shortage, as well as zones that are consuming too much water. Though thermal cameras are still quite costly HiView and FutureWater have explored the market for thermal cameras and found two step-in models that enable further research and are fit for crop monitoring operations at the same time. The first model to work with was the FLIR ONE. This camera served to get acquainted with the use and output of thermal cameras in general. After the FLIR One we progressed to the FLIR DUO R. This camera is a higher resolution than the FLIR One. Moreover, is offers the possibility to set settings for air humidity, air temperature, reflectance intensity, and object distance.

Diverse aspects that are involved with the use of thermal cameras are now object of testing. To name the most important ones:

- Calibration points. Non-reflecting plates from aluminium are laid on the ground to calibrate the thermal images
- Meteo data. Integration with meteo data is needed to refine the outcome of thermal images
- Settings of flight: altitude, speed, capturing time interval, overlap. These settings are well defined as we stand.

3.2.2 UAVs

The actually used UAV is the DJI Mavic Pro. ThirdEye has expanded the number of UAVs to 7. The latest type that were added is the Mavic Pro Platinum. This UAV is part of the Mavic Pro family, but it has some improvements due to design refinement. Lower noise level and longer flying time are the most important improvements.

A comparison was conducted with the bigger brother of the actually used Mavic Pro, namely the Mavic 2. In the framework of another project Jan van Til was in the situation to use the Mavic 2. This type is compatible with the software for mission planning that is actually used with ThirdEye. In every respect the Mavic 2 is serious alternative for the Mavic PRO because it delivers a higher performance. For the time being though ThirdEye has decided to stick with the Mavic PRO (Platinum) because of lower costs.

Figure 7. ThirdEye's modified flying sensors, with a NIR Go Pro camera mounted on the back of the flying sensor.

3.2.3 Image processing

Processing of the images is on-goingly subject to development. An example from the desk of the ThirdEye operator is the finetuning of the color schemes that are applied to NDVI mapping. Firstly operators sticked to one pre-defined color style that is used to classify the NDVI map, enabling to indicate different zones of crop condition. In the last year operators are applying different styles according the crops that are monitored. The result is a more detailed and balanced NDVI mapping.

Two important aspects of image processing were studied thoroughly by Corjan Nolet from FutureWater, CWSI (Crop Water Stress Index) and the stitching of the thermal images in combination with the stitching of RGB in Agisoft Photoscan and Metashape.

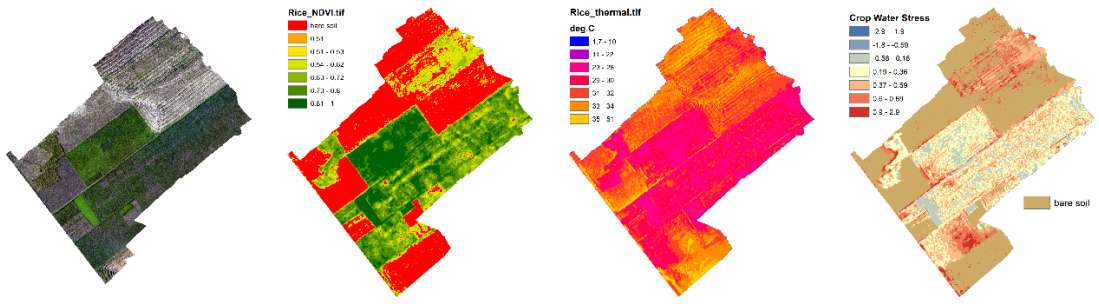


Figure 8. Flying sensor imagery of rainfed rice (Kenya, March 2019) for crop water stress index (CWSI) mapping.

3.3 Training

3.3.1 Initial flying sensor training

In December 2017 the first ThirdEye staff conducted an intensive two weeks flying sensor training at Agricultural Training Centre (ATC) Kaguru, 15 km south of Meru, Kenya. The training was given by our senior staff member Mr. Jan van Til, assisted by ATC's principal Mr. Paul Kiriinya and our local manager Mr. Kiogora Julius. Three young women and two young men from the Meru region, all of them professional extentionists, were promoted "flying sensor operator" at the end of the training, each receiving a ThirdEye certificate.

The operators were fit for the job that consists of conducting flights, processing the images to NDVI crop status maps and giving advice to farmers in the fields with the help of GPS tablets. From January on the

ThirdEye service has been implemented in several Meru sub-counties, where farmers receive advice on a weekly basis. After a few months the service has been expended to new sub-counties. In this process ThirdEye Kenya is slowly transforming from a project into a leading local flying sensor enterprise.

Figure 9. ThirdEye operators receiving training in the classroom and in the field.

After the initial training period several follow-up training sessions for the operators have been organized. These sessions were needed to guide the operators with the use of existing techniques or to inform them about new techniques or approaches, aimed at improving our service.

During the three trips of Mr. Jan van Til to Kenya these training sessions were an important topic, with training being conducted in class and in the field. Besides this, Mr. Jan van Til discusses technical issues and gives training during weekly skype sessions with the complete operating team, every Wednesday morning.

3.3.2 Second flying sensor training

In November and December 2018 new team members were trained and added to the team. This was done by having the experienced operators provide an extensive training course to the new operators. The training was supervised by HiView but could in the (near) future easily be repeated without any supervision. This train-the-trainer system ensures long term company sustainability.

3.3.3 Sales training

In January 2019 the ThirdEye team received a sales and management training by Whitten and Roy Partnership (WRP). The objective of this training was to teach sales and management skills to our ThirdEye flying sensor operators and local manager in Kenya, in order to enable upscaling of the current ThirdEye crop monitoring service and ensure sustainability of its proven impacts on water productivity and farmer income.

As ThirdEye works mainly with local flying sensor operators with a technical and agronomical background, the lack of skills in sales techniques and business management was identified as the main barrier to scale. Therefore, Whitten and Roy Partnership (WRP), a sales consultancy with extensive

experience in direct sales and strategy in the smallholder agriculture sector, provided 5 days of in-person sales training to our operators. This training was followed by 2 days of in-person management training to the local ThirdEye manager. During and after the training a sales workbook, sight seller, dashboard and sales talk were prepared for the team to make use of.

Ever since this successful training, ThirdEye has been able to expand its commercial activities and was able to transform into the leading flying sensor data service provider in Kenya. The training has provided the operators and local representative the tools to sell the service successfully to farmers throughout Meru Country and beyond.

Figure 10. All ThirdEye operators received their certificates after successfully completing the sales training.

3.3.4 Additional training

To improve their computer skills, three operators, Ian Mwirigi, Fridah Kagwiria and William Mithika conducted a course on basic skills and programs. They all obtained their certificates and greatly improved their expertise during the first year.

Apart from this, in April 2018 all operators have received additional training from SoilCares on soil sampling. After this training operators are equipped with the knowledge on how to adequately take a soil sample in a field and make sure it is ready to be tested by the SoilCares team in the Farmer's Centre in Meru.

Recently, the operators also received soil testing training by Cropnuts and training on the use of organic fertilizers by Lentera Africa (see section 6.6).

3.3.5 Providing expert trainings

Since May 2018 the ThirdEye team is incorporating the flying sensor training itself in their business model, as part of the sales strategy. In this way companies, NGOs, knowledge institutes, governmental organizations and individuals can obtain training on the use of flying sensors in agriculture, basic or advanced. The idea is that the flight training is given at the location of the company and advanced image processing training is given at the office of ThirdEye at Kaguru ATC in Nkubu.

Figure 11. Training at a school in Meru.

Lately, the team also conducted several trainings staff from universities in Kenya and agriculture and water experts from Uganda, Tanzania and South Sudan (Figure 12).

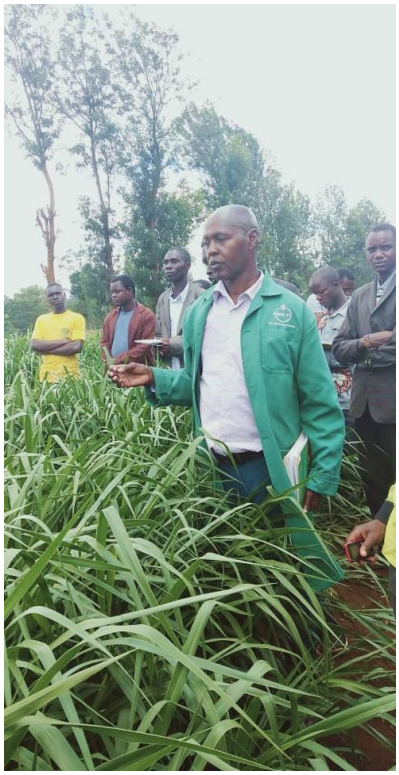


Figure 12. Training of water experts from Sudan in Nakuru.

3.4 Dissemination activities

3.4.1 Policy makers and key stakeholders

The ThirdEye team attended several Irrigation Acceleration Platform (IAP) meetings and had meetings with the County Government of Meru, County governor, Caritas, Kaguru ATC, Shalem, Farmers Centre, Soil Cares, IFDC, Egerton University, Jomo Kenyatta University, KALRO, Juhudi Kilimo and many other stakeholders.

Figure 13. Meetings with the Meru County Commissioner (left) and Deputy Governor (right).

Meetings with both the county governor and commissioner were arranged by the head of Kaguru en Caritas, who had their useful connections. These meetings lead to approval of flying sensor flights in Meru county and full support by all sub-departments. Having this support was crucial for the growth and sustainability of the ThirdEye business.

3.4.2 Presentations and demonstrations

Over the past two years we gave several trial demonstrations of our innovation at the field days, presentation sessions, conferences, etc. in Kenya.

Figure 14. Trial demonstrations at the field day in Meru.

Apart from this, we gave demonstrations for the staff of SNV, Kaguru ATC and Caritas. We also gave demonstrations to large and smallscale farmers in the field.

Figure 15. Example of demonstrations in the field for smallscale farmers.

Also, in the Netherlands, FutureWater and HiView regularly gave presentations and demonstrations on the ThirdEye service.

Figure 16. Flying sensor workshop for the SWA delegation visiting Wageningen, the Netherlands.

3.4.3 Media coverage

Interviews with ThirdEye team members were broadcasted multiple times on the local radio and television. Also, ThirdEye featured in the Next Frontier of KTN News Kenya, a nationwide TV station with millions of viewers.

we completely redesigned the ThirdEye website (www.thirdeyewater.com), making it more attractive and easier to find what you are looking for. We also made several news articles on the project, on the FutureWater, HiView and ThirdEye websites. Moreover, we are very active on ThirdEye's Twitter account.

4 Impact

4.1 ThirdEye service areas

Figure 17 gives an overview of all working areas of the ThirdEye team. These service areas have slowly been expanded over the course of time, starting in Meru (pink) and slowly expanding (yellow) towards other counties (orange).

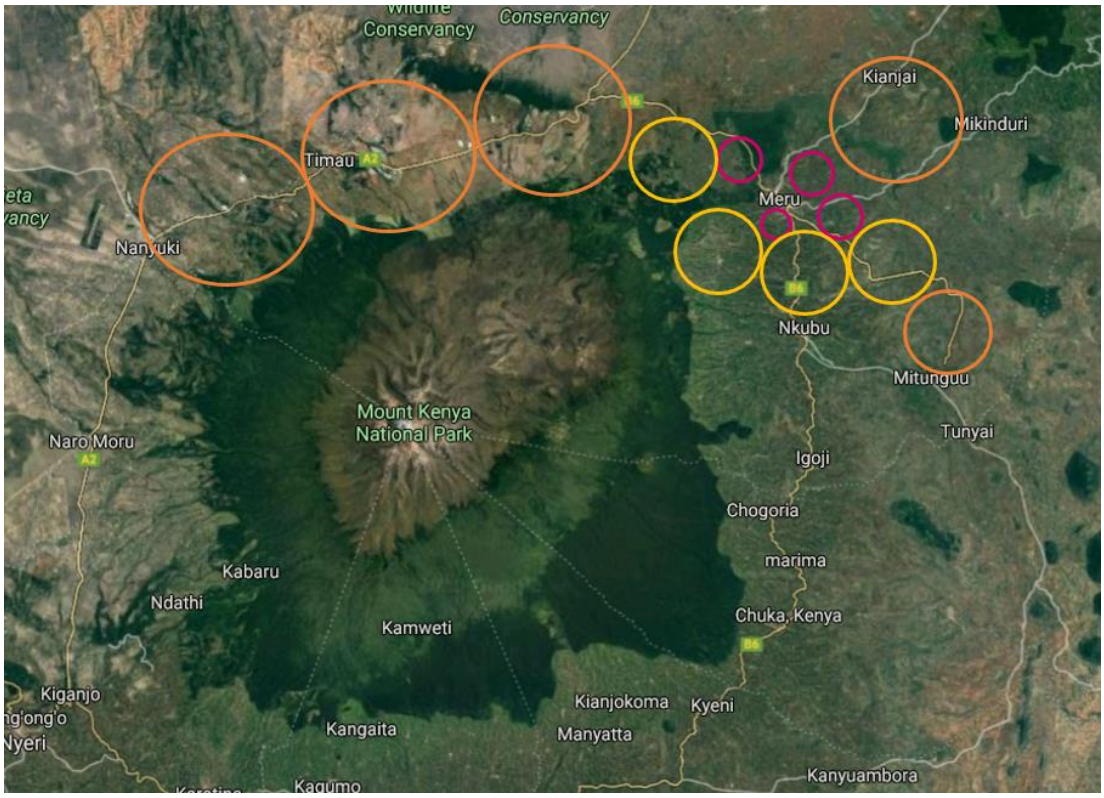


Figure 17. Expansion of ThirdEye's service areas over the past two years, starting in Meru (pink) and slowly expanding (yellow) towards other counties (orange).

ThirdEye has permission to perform flying sensor flights in Meru County, but since geographical expansion is essential to scale up ThirdEye Kenya even further, is currently in the process of issuing a national flight permit. Given the initial talks we had so far and the experience we have in other developing countries (Ghana, Mozambique), the risk for not being able to obtain a national flight permit is considered low.

4.2 Farmers and acres served

Since the start of the ThirdEye service in Kenya 2044 farmers received the ThirdEye service. Considering an average household size of 4.7 persons[1] a total of 9607 persons were positively affected by the service. A list of all farmers that received the ThirdEye service is attached to this report.

The service was provided on a total area of 4217 acres (1707 ha), with 25% of the land used for cabbage production, 15% for tomato and 60% for other crops.

[1] According to "Household population and housing characteristics" by The DHS Program/FM Munene. https://dhsprogram.com/pubs/pdf/FR151/02Chapter02.pdf

4.3 Change in water productivity

FutureWater conducted a technical analysis on the change in water productivity for farmers who received the ThirdEye service. Only a brief summary of the results of this study are provided in this section. The full details of the analysis can be found in a separate report (ThirdEye Kenya – Water Productivity Report, FutureWater Report 190, December 2019).

'Water Productivity' is a concept used frequently in agricultural water management. It represents the amount of production that is achieved with a certain volume of water. In this study water productivity is defined as biomass production per volume of consumed water, which is evapotranspiration. The approach for this water productivity analysis was using satellite data in combination with an algorithm for estimating water productivity. Three areas, where ThirdEye activities were conducted, were selected for an analysis of the water productivity (Figure 18). Each ThirdEye study field was paired with a control field with similar weather conditions and cropping pattern.

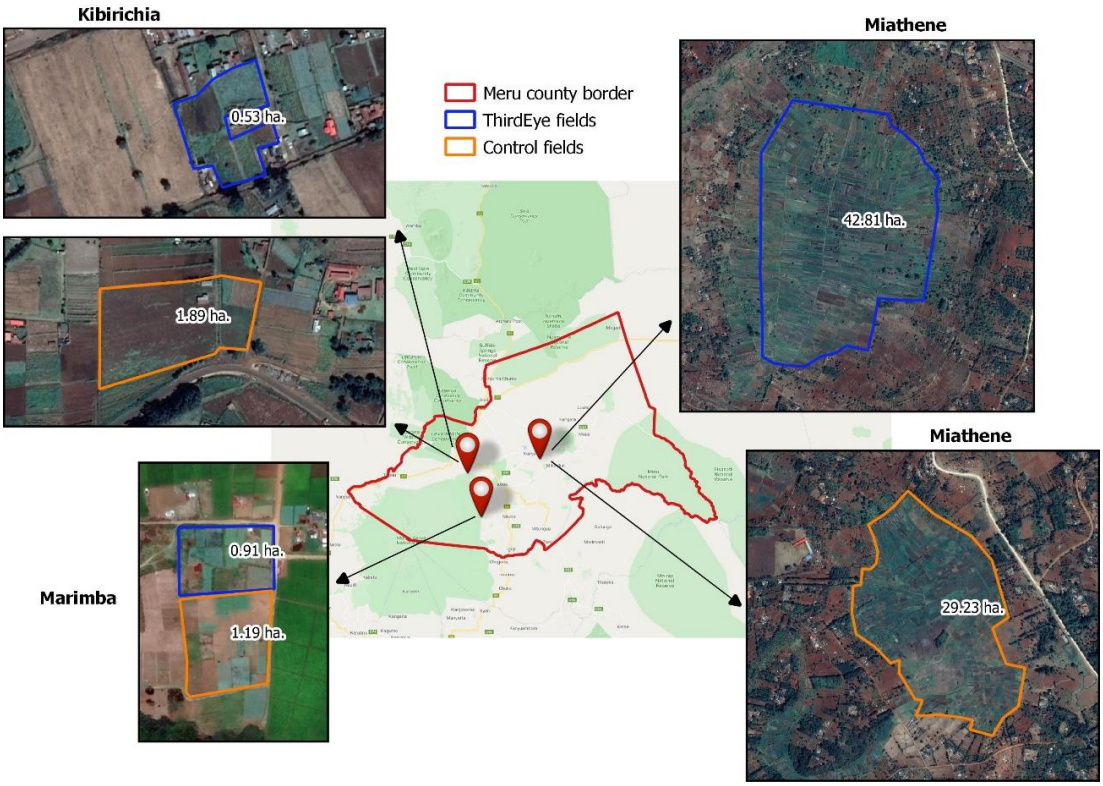


Figure 18. Location of ThirdEye and control fields including area size in hectares.

The results for water productivity from the 17 Landsat images were analysed and used to determine an average water productivity for each crop growing season. Results of this comparison is displayed in Figure 19 for the three seasons of analysis. The ThirdEye fields are indicated in blue colour and the control fields in orange colour. For the Kibirichia location the water productivity of the ThirdEye fields were higher for each season. The difference between the ThirdEye and control fields was largest in the second 2018 season. For the Marimba location the water productivity was higher for both 2018 seasons and was similar in the 2019 season.

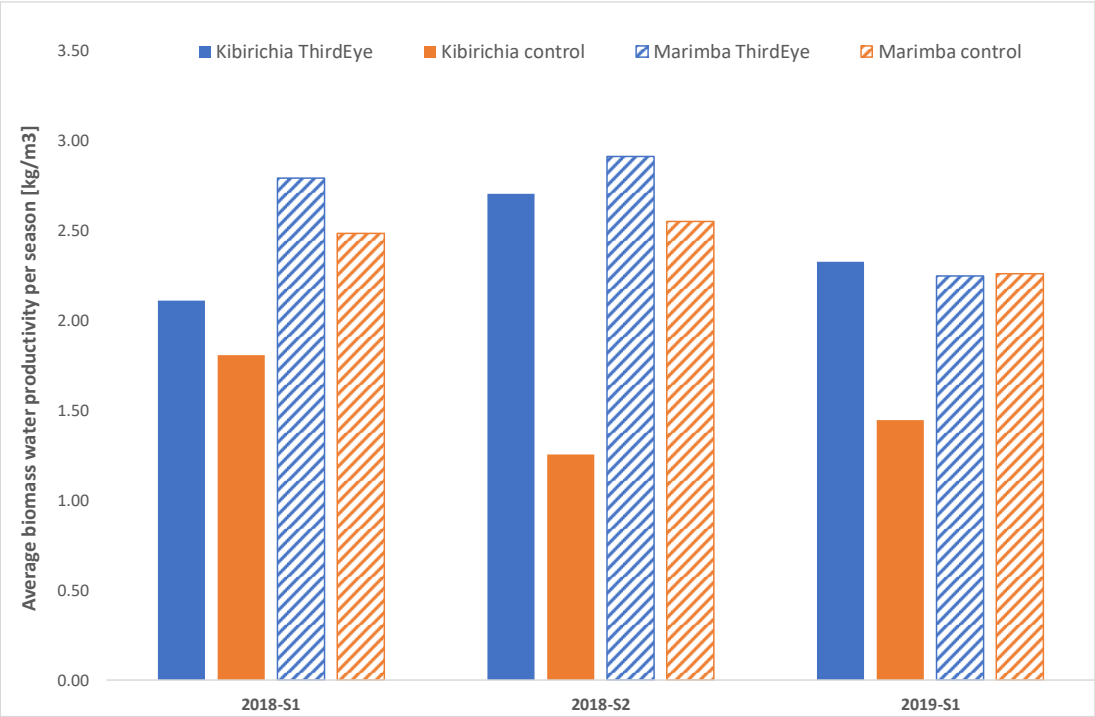


Figure 19. Average biomass water productivity for each growing season.

The average difference in water productivity for each growing season are presented in Table 1. The largest impact on water productivity was achieved in the Kibirichia location. The water productivity had an overall average increase of 33% and ranged between 12% to 54% per season. For the Marimba location the overall water productivity increase was 7%, with the largest increase of 12% in the second season of 2018. The second season of 2018 displayed the highest difference for both fields indicating that the ThirdEye activities implemented in this season were successful and had the most impact.

Table 1. Average percentage difference between ThirdEye and control fields per growing season.

Year	Season	Location	
		Kibirichia	Marimba
2018	S1	12%	3%
	S2	54%	12%
2019	S1	33%	6%
Overall average		33%	7%

In conclusion, the results of this technical study display an increase of water productivity for the Kibirichia and Marimba locations, indicating a positive impact of ThirdEye activities in this region. The overall average increase achieved for Kibirichia is 33% and for Marimba it is 7%. These results are based on a comparison using satellite derived water productivity results. Even though inaccuracies were encountered in the outputs of the satellite derived results (mainly due to cloud cover issues), the outputs were sufficient to make an insightful comparison of the impact of ThirdEye during this project period.

4.4 Change in yield and revenue

Thanks to the ThirdEye service a water productivity increase was realized. Since most of ThirdEye's advisories were about boosting soil nutrients or diminishing pests, this increase is mostly caused by an increase in crop production and not by a decrease in irrigation water usage. Therefore, the total yield increase as a result of the service was considered to be 20% as well.

Taking into account the Kenyan control yields of cabbage[1] (57.5 tonnes/ha), tomato[1] (40 tonnes/ha) and other crops[2] (1.9 tonnes/ha) the total control production was calculated to be 36.7 tonnes for control areas and 44.1 tonnes for areas that received the ThirdEye service. The total yield increase as a result of the service was therefore 7.3 tonnes. If these crops would have been grown on traditional farmland (i.e. without ThirdEye services) 341.3 ha would be needed (478 football fields). Considering an average crop water requirement of 500 mm[1] and 250 mm of rainfall, 250 mm of irrigation water would be needed to produce these crops and with 90%[3] of farmers applying irrigation a total of 767,952 m^3 of water would have been applied to this additional farmland and is therefore, as a result of the ThirdEye service, indirectly saved.

The 20% increase in yield lead to an equal increase in revenue. Considering the proportion sold on the market for cabbages[3] (71%), tomatoes[3] (71%) and other crops[4] (24%) and the average price per kg for cabbages[1] (12.5 KES), tomatoes[1] (22.5 KES) and other crops[5] (30 KES) the total increase is revenue equals more than 79 million KES (667,910 euro). Per farmer the revenue increase comes down to 38.7k KES (327 euro).

[1] According to "Smart Water for Agriculture, Kenya - Interaction of water regulation arrangements and water productivity with current irrigation systems and promising Smart Water Solutions in Naro Moru catchment, Laikipia, Kenya" by Frederik Jansen and Marianne Bosman (July 2017).
[2] Average yield derived from several online sources, such as the FAO report and http://www.yieldgap.org/kenya.
[3] According to “Smart Water for Agriculture Project - Baseline Survey Report (December 2016)”.
[4] Smallholder average according to "The economic lives of smallholder farmers - An analysis based on household data from nine countries" by FAO. Also in line with SNV's "Smart Water for Agriculture Project - Baseline Survey Report (December 2016)".
[5] Average price from in-field consultation and according to multiple websites.

5 Success stories

5.1 Mr. Mugiira: in-time pest control

We were able to take flight in this field, which was 5 acres and the identified problems were rust on the tomatoes and fusarium wilt. Mr. Mugiira was able to control the problem in time. When early blight, rust and fusarium wilt are detected earlier they can be treated, but when the problem becomes severe the chances of controlling it becomes minimal. Thank you for ThirdEye technology that can be able to identify these challenges before they get out of hand to control.

5.2 County Executive Commissioner of Agriculture: giving full support

Professor Karwitha who is the County Executive Commissioner of Agriculture is in full support of technology especially the commercial aspect of ThirdEye. We were able to take a flight with her at Ruiri on 10 acres green grams piece of land and detailed report was presented to her.

Figure 20. ThirdEye operators with Meru County Executive Commissioner of Agriculture on May 2018.

5.3 Caritas demonstration farm: eliminating fusarium wilt and whiteflies

This was a commercial flight taken by our operators on Caritas field at Ruiri, we were able to take flight on their 5 acres of land planted kales, tomatoes, capsicum and green beans. Results showed that most of tomatoes were affected with fusarium wilt and kales were attacked by pest called whiteflies. Thanks to the ThirdEye service these diseases could be detected and were eliminated in time.

Figure 21. Vyonne ThirdEye operator explaining to Mr. Gitau from Caritas the Nature of crop.

Figure 22. Mr. Gitau from Caritas examining the status of chilies after presenting the results.

5.4 Mr. Kithinji and Mr. Kimathi: flights, soil tests and organic inputs

Mr. Joses Kithinji and Kenneth Kimathi are two farmers in Kanyakine who are benefiting from ThirdEye drone service.

Mr. Joses Kithinji, who heard about ThirdEye services from one of local radio station, called to enquire about availability of services, started with drone services from one of the qualified Agronomist and drone operator Benson Mwaura, after advisory services he was advised on the need of doing soil testing on his farm before planting new crops, after the soil test the crops did well and he increased his maize harvest. On the section of his farm that he had grown green grams he was advised on products to use that were organic in nature. The combination of ThirdEye services and agronomic skills from experienced operators boosted his harves.

Mr. Kimathi is also a prolific bananas and coffee farmer in the region who has increased his harvest through the advice disseminated to him by ThirdEye operators.

Figure 23. ThirdEye in the field of Mr. Kimathi.

5.5 Mr. Maina: doubling yield

Through introduction of ThirdEye services Nanyuki which is in Laikipia county, Mr. Maina can now produce double the production he used to produce before, He was able to realize 100% increase in production of French beans in 0.8 acre of land, thus doubling his income, before he used to harvest around 6 bags of French beans per week but later after ThirdEye intervention he was able to produce 12 bags of French beans per week.

With one bag weighting 10 kgs and the market price per kg being 40 KES, he increased his revenue with 2400 KES per week for a harvest period of 11 weeks. His total revenue increase was therefore 26,400 KES. The costs for this revenue increase was two-fold: he paid 200 KES for the ThirdEye service and 375 KES for the recommended fertilizer to boost his productivity, totalling to 575 KES. Overall the result of the ThirdEye intervention was an additional 25,825 KES of income.

Figure 24. In the field with Mr. Maina.

5.6 Mr. Bernard Munene: attracting regional farmers

Mr. Bernard Munene a farmer in Timau with around 7 acres of land, planting cabbages, maize ,beans, tree tomatoes, oranges has been receiving ThirdEye services for about an year says that it has really helped him make precision decisions on his farm he can happily see a total increase in production in all his farm enterprises. His previous maize harvest for 5 acres of land was about 36 bags but in 2019 he expects double this which is a big improvement. He always makes a call for crop stress monitoring and his farm has really attracted more farmers who are always referred for us to offer the service. This increases acquisition in the area. Farmers are happy about the results in their farms.

Figure 25. Operator Veronicah and Mr. Bernard Munene inspecting his crops.

6 Business development

6.1 Stakeholders

The figure below gives an overview of how the different stakeholders are working together to turn ThirdEye Kenya into a success.

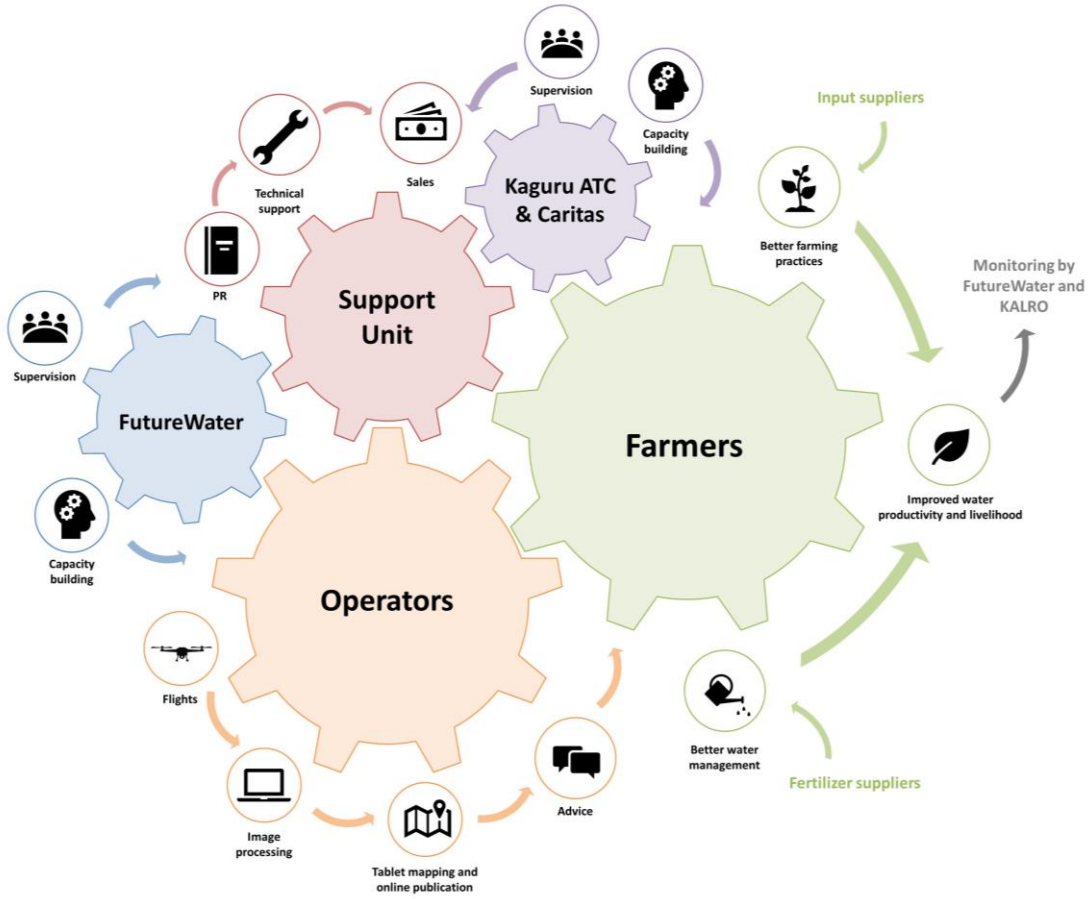


Figure 26. Workflow between the different partners.

6.2 Transition phases

Over the past two years, ThirdEye Kenya made the transition from a subsidy-funded project toward a commercially viable company. This transition was done is six different phases:

- Phase 1: Early introduction and training of the operators
- Phase 2: Awareness creation campaign and free service provision
- Phase 3: Paid service provision
- Phase 4: Sales boost (bundling of services, sales training, improved business model)
- Phase 5: Upscaling (training of additional operators and assignment of sales manager)
- Phase 6: Sustainable local business, ready for geographic expansion

In the first months FutureWater and HiView trained ThirdEye operators and set up a local support unit. The support unit's main tasks are to provide technical support to the operators, conduct sales of the service to individual farmers, farmer associations, agribusiness companies and governmental organizations and public relations. This support unit was set up together with SNV's Irrigation Acceleration Platform (IAP) partners in the region, Kaguru ATC and Caritas, who also focus on capacity

building of farmers. They helped in the recruitment of the operating team and finding the best local representative. In phase 2 the service was given free of charge to make farmers acquainted with the technology and to have operators get used to their activities. After this a gradual transition was made to more and more paid services in phase 3. In phase 4 sales were boosted by having a sales training for the team, bundling with different other services, and further defining the business model. In phase 5, reached early 2019, the operating team was expanded with additional operators and a sales manager. At this moment, as ThirdEye is in phase 6, long-term sustainability is ensured, a train-the-trainer system is in place and geographic expansion is possible.

The different phases are shown in the figure below.

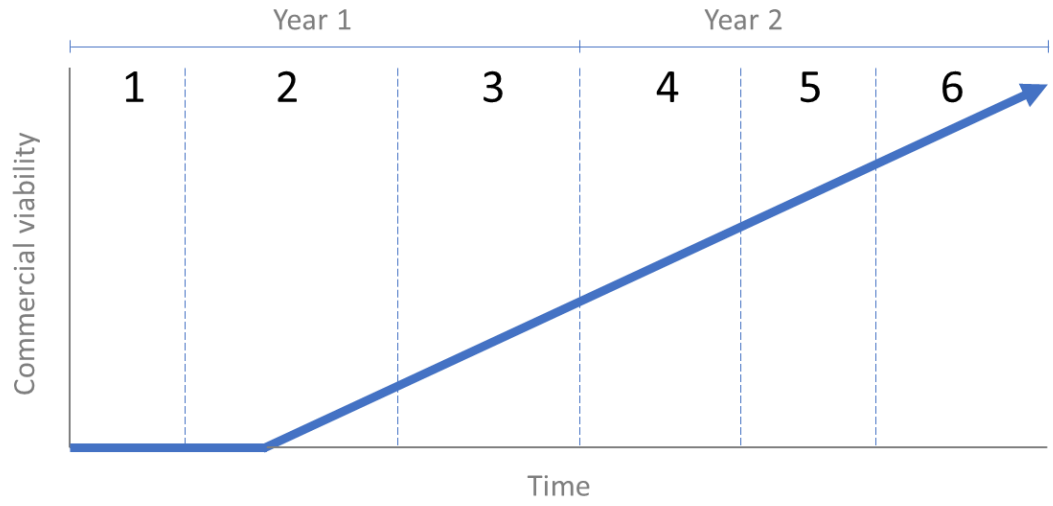


Figure 27. The schematic development of ThirdEye Kenya, in different phases.

6.3 Pricing and commission

Since March 2018 the ThirdEye team adopted a new strategy to boost commercial sales. First of all, the price for the service was set at 150 KES per acre, with a minimum of 300 KES. In-field surveys with farmers indicated the willingness to pay for the service at this cost is reasonably high. Furthermore, the operators indicated this price would be a very reasonable start-up price, on the low side of the extension service spectrum, which could be increased in the future if required.

In the beginning, 25% of the sales went to the operator(s) acquiring the client as a commission, 50% to the one(s) conducting the flights and advisory and 25% stays as a reserve in the ThirdEye company. This commission-based approach encouraged the operators to make sales. This commission structure was slowly changed over the course of the past two years, where now operators receive a part of the sales they make. The amount of time that operators have available to make commercial sales has also been increased gradually since the start of the operational services, from 0 to 100% of their time currently.

6.4 Franchise structure

FutureWater is seeking to set up its operations in Kenya in accordance with a “light” business model, which can be easily implemented without heavy supporting structures and costs (the company chooses not to heavily invest in assets in the country), is seeking some equal risk taking from local partners, and is easily expandable into other geographical areas. With this in mind, an initial business model for the service was made early on in the project (Figure 28).

The idea was to set up a central “Support Unit” which on a flexible basis provides the necessary support to the operators (or local managers, who may act as technical operator or outsource technical operations) in different locations. This is best served by setting up a single unit franchise structure.

It allows FutureWater and IAP partners to be able to expand a network of interdependent business operators effectively and efficiently. The investment requirement is low, however proper emphasis should be given on providing the right support to local operators (i.e. the franchisees). For the franchisee, the advantages include a low threshold in stepping into the business: the operator does not need to acquire assets, rather it invests in an operating system through which it can present ThirdEye, effectively sell ThirdEye services, and collect revenues. To that end, “ThirdEye Kenya” would act as local franchise holder supporting the operations in any geographical location where local operations will be set up. In a single unit franchise relationship, the franchisor grants to the franchisee the right to operate one location using the franchisor’s trade name, service marks, and operating system. This means that the franchisor should enter into a franchise agreement with every franchisee. From a managerial and operational point of view it is more beneficial to have each location covered by a separate franchisee, moreover as both locations are characterized by different market dynamics and hence require different operational business models. The proposed single-unit franchise system will allow the franchisor to test the commercial relationship with the operator before eventually allowing the franchisee to open up new facilities in the area, if so applicable.

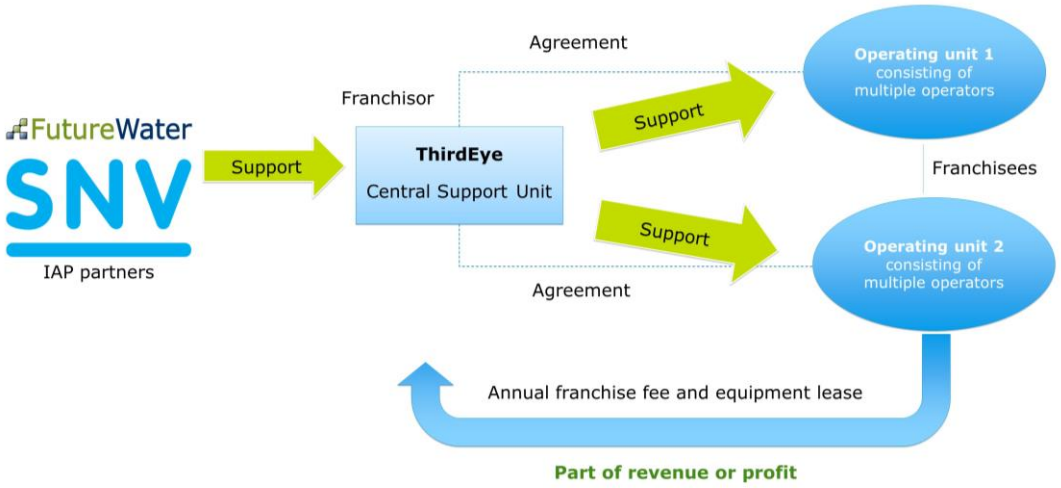


Figure 28. ThirdEye business model.

Over the past two years, the central support was set-up, including one operating unit in Meru. Expansion of the project to new counties (Meru, Laikipia, Nyeri, Kirinyaga and Narok in the potato and green grams value chains), which is proposed in a follow of project by ThirdEye, Lentera, FutureWater and HiView, as part of the Climate Resilient Agriculture For Tomorrow (CRAFT) project by SNV, would allow more operating units to be set up, under the supervision of the central support unit.

6.5 Revenue streams

The three different revenue streams that have been identified are shown in the figure below. The ThirdEye operating unit, in a certain area, supported by the central support unit, can sell the service directly to (semi-) commercial producers, smallholder farmers (who are e.g. paying through the Water Resources Users Association (WRUA) or farmers’ association), the sub-county itself and processors who work with smallholder farmers. In case of the latter, the service is delivered to smallholder farmers, who sell their harvest to processors (i.e. contract farming). These processors benefit from buying the

service for their smallholder producers by getting more and higher quality inputs for their production process.

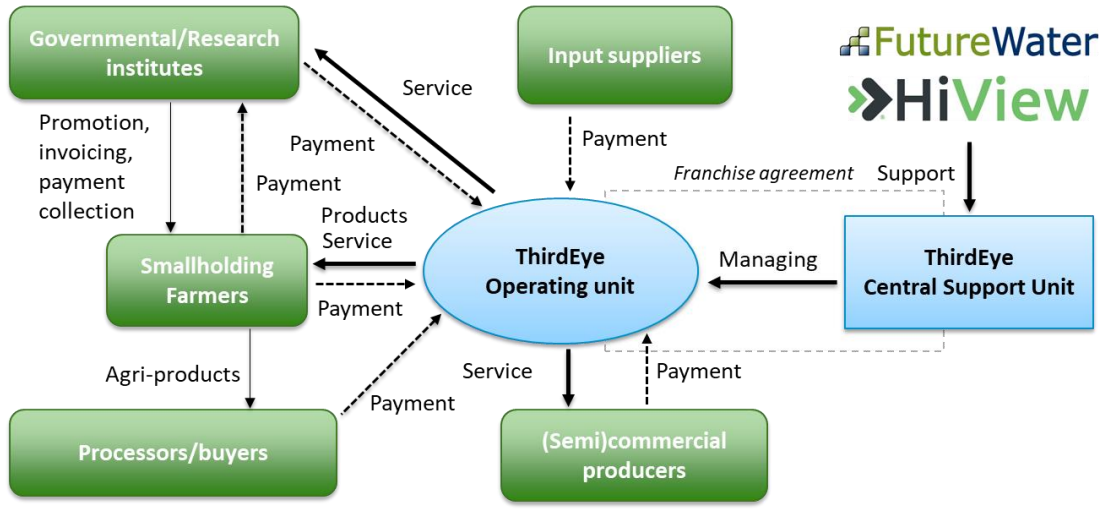


Figure 29. Overview of identified revenue streams.

6.6 Bundling of services - Multiplier effect

Since May 2018 we have partnered extensively with the Farmers Centre and SoilCares to bundle our ThirdEye service with the soil testing service offered by SoilCares. Farmers can use this service to test their soils. Samples are analyzed in the SoilCares lab in the Farmers Centre in Meru. Every soil test, including analysis report, costs a farmer 1300 KES. After receiving training by SoilCares staff, the ThirdEye operators are now able to take soil samples themselves, for which the farmer still pays 1300 KES per sample. Of this amount 1000 KES goes to SoilCares and 300 KES is for the ThirdEye company. Results are emailed within a few hours to our local staff, who are able to print it in the ThirdEye office and take it back to the farmer, together with our ThirdEye service advisory.

Since May 2019, ThirdEye has successfully teamed up with Lentera Africa LTD. Lentera is a leading Kenyan farming technology company enabling farmers increase their yields and adapt to climate change through climate smart inputs, precision agriculture and conservation agriculture. Lentera has a portfolio of organic and mineral based climate smart inputs including Organic Phosphate planting fertilizer, Silicon foliar fertilizer (drought tolerance bio stimulant), NPK foliar fertilizers, and Micronutrient foliar fertilizers. Together with Lentera ThirdEye is now supplying organic fertilizers to farmers who require these inputs.

Lentera's CropNutrient Silicon Foliar Fertilizer is a unique bio-stimulant and micronutrient fertilizer blend which provides silicon in a form that plants can take up with proven benefits: (1) Increase size, weight and yield of your produce, (2) Increase resistance to pests and diseases, (3) Increased tolerance to dry weather conditions (that will become more predominant due to climate change), and (4) Improved uptake of nutrients (meaning less fertilizer is leaching out into the environment). Futhermore, it is 100% natural which means the produce can be labeled 'organic' for which the demand is continuously increasing, driving up the price and thus income for farmers and their families. Using ThirdEye's flying sensors it is ensured that targeted applications are done to zones that are facing crop stress thus protecting the yield and at the same time saving costs associated with blanket application of pesticides and fertilizer.

7 Financial analysis

A financial analysis was performed to assess the costs, net benefits and the return on the investments.

7.1 Benefits

On 16 March the ThirdEye team made its first sale to several farmers in Miathene. In May 2018 ThirdEye was registered as official limited liability company in Kenya. This was needed in order to be able to pay out wages to our operators and to set-up a bank and M-Pesa account in July 2018. Ever since, farmers have started paying to this new account, which is used by almost every farmer, and sales have gone up steadily (Figure 30).

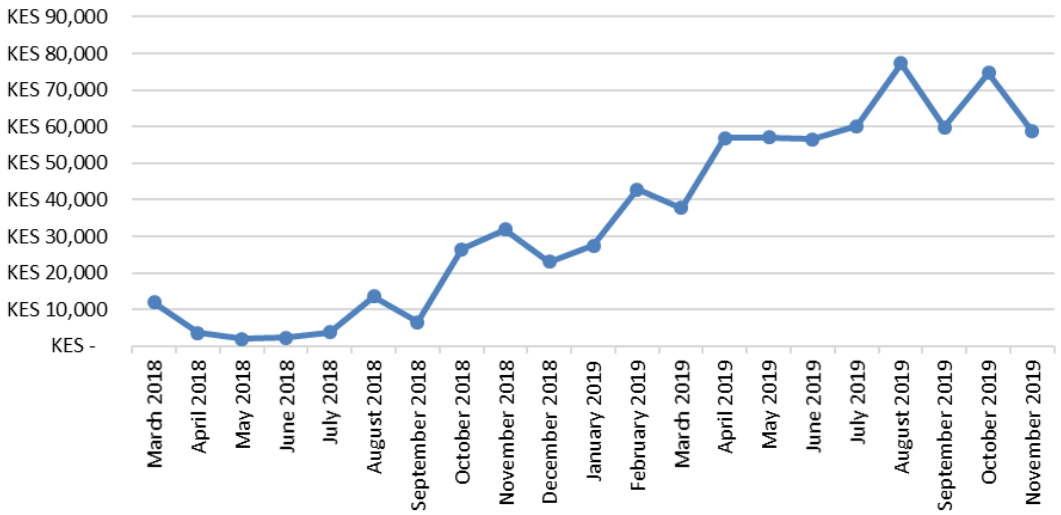


Figure 30. ThirdEye total sales per month.

Total sales have reached KES 733,875 so far.

Figure 31 shows the expected yearly revenue for the coming ten years. This graph was updated with the actual sales over the past months, compared to the one in the Business Plan of January 2019. Revenue estimates were also made for two other scenarios. The light grey dotted line shows a scenario in which sales are one-third lower than expected and the dark grey dotted line shows the scenario for an increase in sales of 50%.

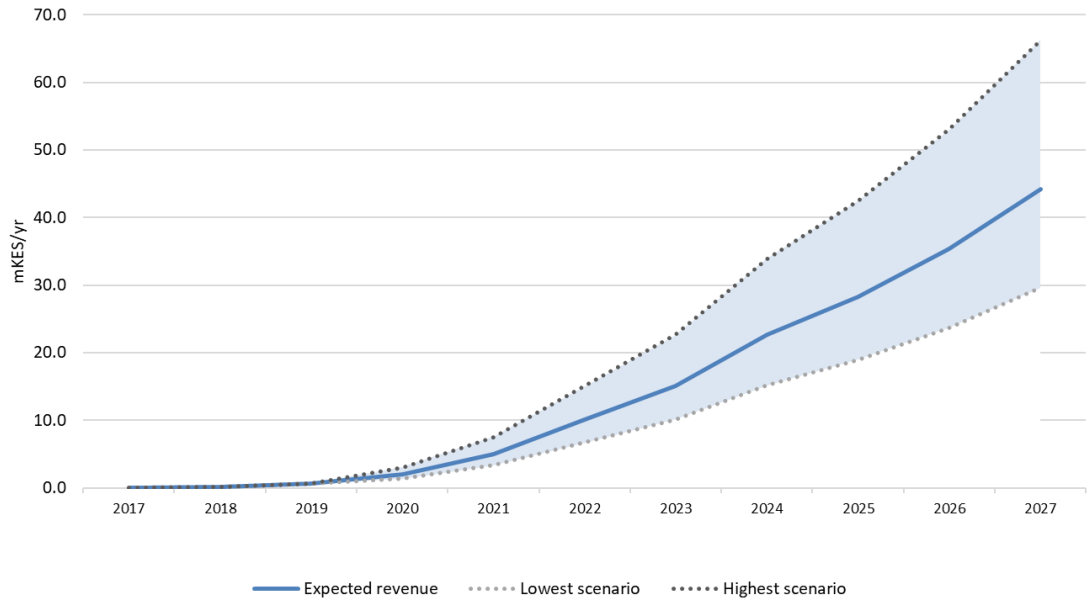


Figure 31. Total actual and forecasted yearly revenue over time (in KES million) for low, medium and high revenue scenarios.

7.2 Net benefit

To assess whether the investment in ThirdEye pays back within a reasonable time horizon, a return-on-investment analysis was performed. For this, the investment costs as well as the operating costs of the company were considered. Figure 32 shows the actual annual benefits, costs and net benefits for 2017, 2018 and 2019 and how they are anticipated to be realized over time.

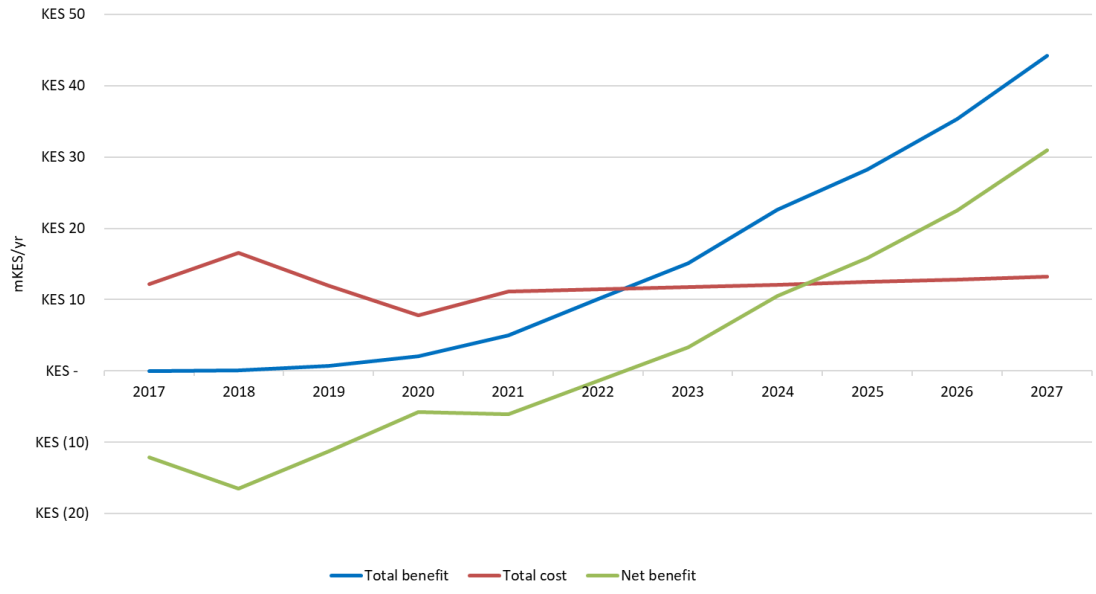


Figure 32. Total annual benefits and costs over time (in KES million) for the medium revenue scenario.

7.3 Net present value

The appropriate framework for considering the benefits against costs is to use discounting to convert benefits and costs into present values, which accounts for the fact that benefits and costs have different

values depending on when they are realized. Figure 33 shows the same net benefit line as in Figure 33, but also shows the Net Present Value (NPV) at any point in time, assuming a discount rate of 4%. The NPV figure captures the discounted costs and benefits as they accumulate. Once the NPV line crosses above zero, the investment has reached viability. As can be seen, this happens within a timeframe of 7.5 years from now for the medium revenue scenario and within 5.5 years for the highest scenario.

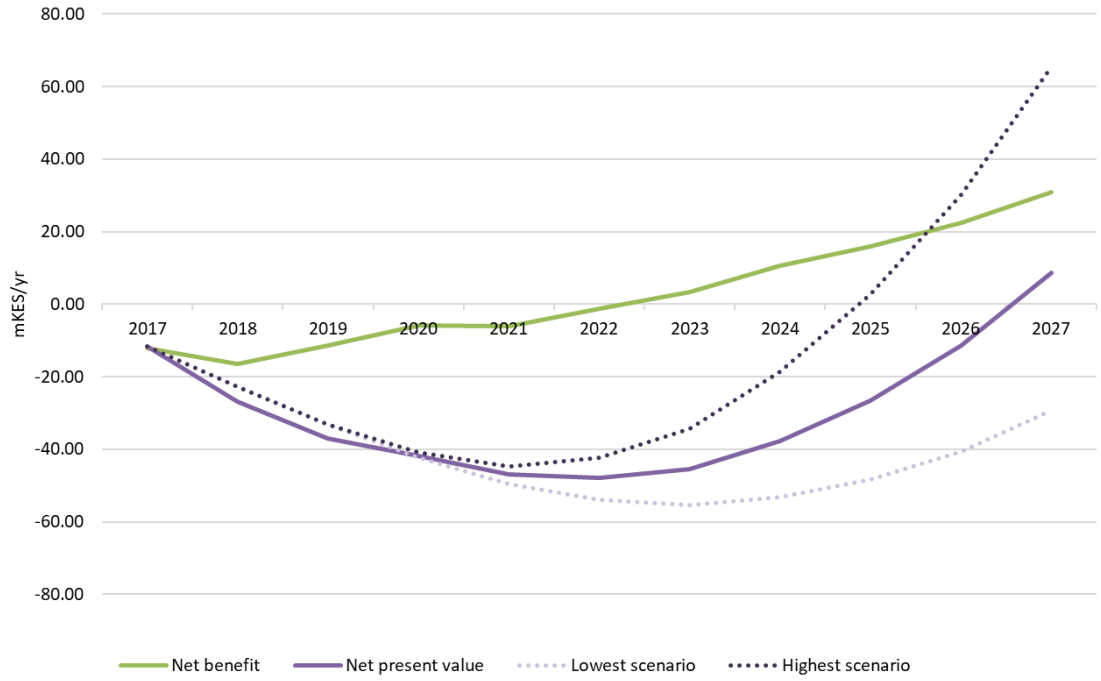


Figure 33. Annual net benefits and Net Present Value of the medium revenue scenario.

7.4 Return on investment

To assess how the return-on-investment plays out for other scenarios and assumptions, Table 2 shows the Return-on-Investment (RoI) after 10 years.

Table 2. Return-on-investment analysis for the three scenarios.

Revenue scenario	Low	Medium	High
RoI after 10 years	-18%	23%	83%

As can be seen, with the discount rate of 4%, the medium and high revenue scenarios are highly profitable within a time horizon of 10 years.

Appendix 1: Company registration documents

No. **PVT-Y2URYBV**

CERTIFICATE OF INCORPORATION

I hereby **CERTIFY** that,

FARM THIRDEYE CONSULTANCY LIMITED

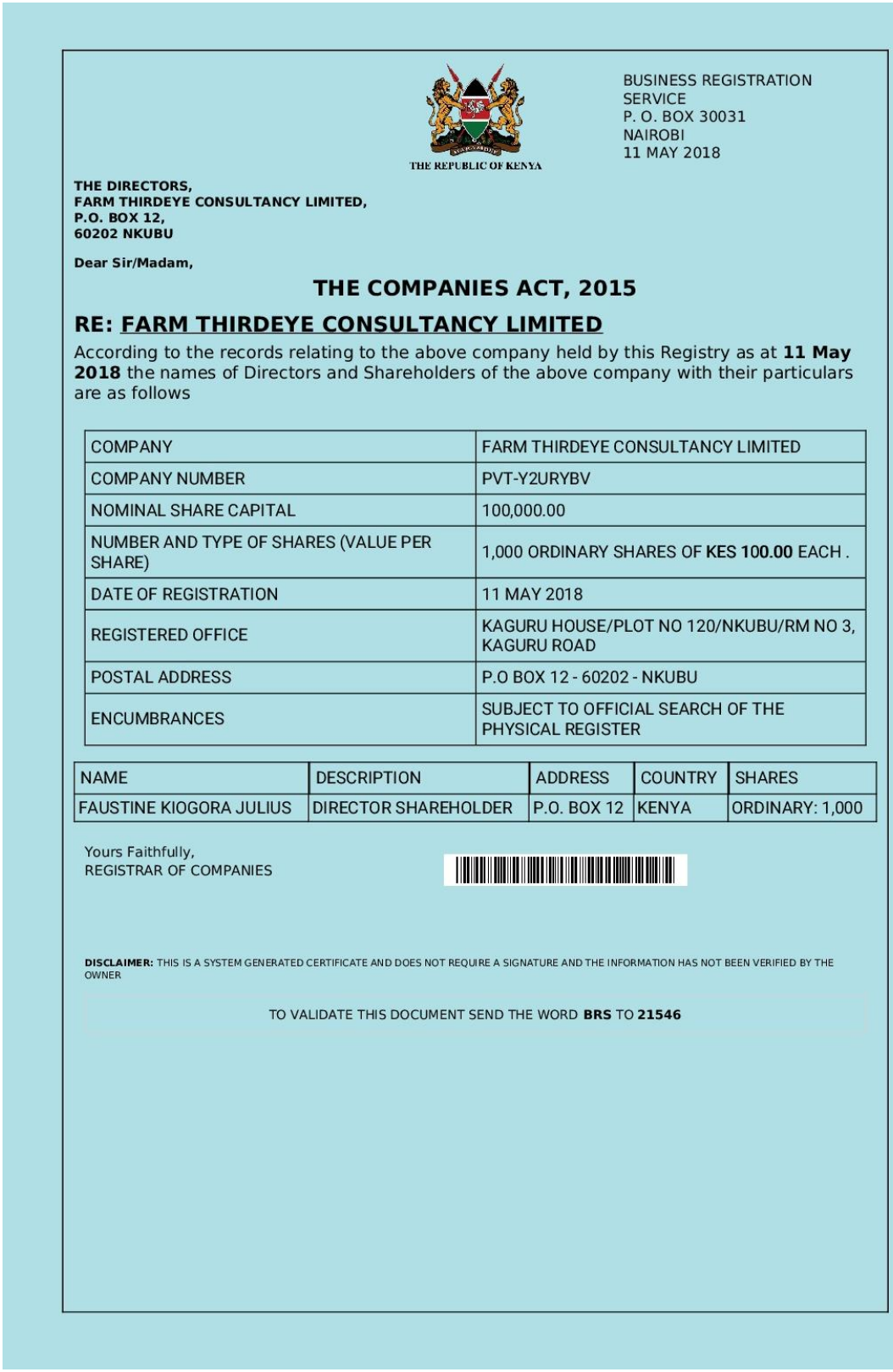
is on this date 11 May 2018 Incorporated under the Companies Act, 2015 and that the Company is a **PRIVATE LIMITED COMPANY.**

.....

Registrar Of Companies

This is a system generated certificate. To validate this document send the word **BRS** to **21546**

Registration certificate.



THE REPUBLIC OF KENYA

BUSINESS REGISTRATION SERVICE
P. O. BOX 30031
NAIROBI
11 MAY 2018

THE DIRECTORS,
FARM THIRDEYE CONSULTANCY LIMITED,
P.O. BOX 12,
60202 NKUBU

Dear Sir/Madam,

THE COMPANIES ACT, 2015

RE: FARM THIRDEYE CONSULTANCY LIMITED

According to the records relating to the above company held by this Registry as at **11 May 2018** the names of Directors and Shareholders of the above company with their particulars are as follows

COMPANY	FARM THIRDEYE CONSULTANCY LIMITED
COMPANY NUMBER	PVT-Y2URYBV
NOMINAL SHARE CAPITAL	100,000.00
NUMBER AND TYPE OF SHARES (VALUE PER SHARE)	1,000 ORDINARY SHARES OF **KES 100.00** EACH .
DATE OF REGISTRATION	11 MAY 2018
REGISTERED OFFICE	KAGURU HOUSE/PLOT NO 120/NKUBU/RM NO 3, KAGURU ROAD
POSTAL ADDRESS	P.O BOX 12 - 60202 - NKUBU
ENCUMBRANCES	SUBJECT TO OFFICIAL SEARCH OF THE PHYSICAL REGISTER

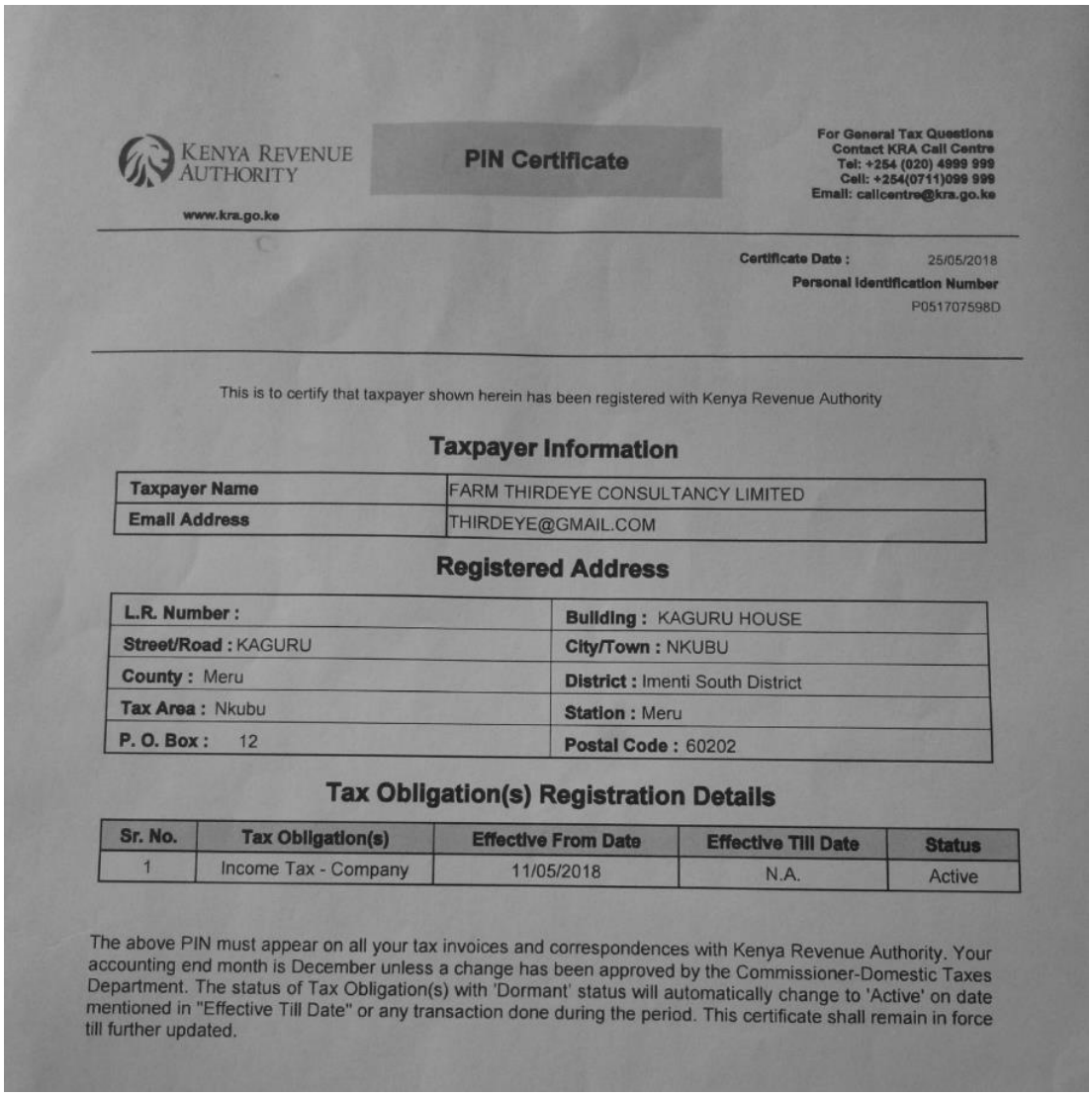
NAME	DESCRIPTION	ADDRESS	COUNTRY	SHARES
FAUSTINE KIOGORA JULIUS	DIRECTOR SHAREHOLDER	P.O. BOX 12	KENYA	ORDINARY: 1,000

Yours Faithfully,
REGISTRAR OF COMPANIES

DISCLAIMER: THIS IS A SYSTEM GENERATED CERTIFICATE AND DOES NOT REQUIRE A SIGNATURE AND THE INFORMATION HAS NOT BEEN VERIFIED BY THE OWNER

TO VALIDATE THIS DOCUMENT SEND THE WORD **BRS** TO **21546**

Registration details.



KENYA REVENUE AUTHORITY

www.kra.go.ke

PIN Certificate

For General Tax Questions
Contact KRA Call Centre
Tel: +254 (020) 4999 999
Cell: +254(0711)099 999
Email: callcentre@kra.go.ke

Certificate Date : 25/05/2018

Personal Identification Number
P051707598D

This is to certify that taxpayer shown herein has been registered with Kenya Revenue Authority

Taxpayer Information

Taxpayer Name	FARM THIRDEYE CONSULTANCY LIMITED
Email Address	THIRDEYE@GMAIL.COM

Registered Address

L.R. Number :	**Building :** KAGURU HOUSE
Street/Road : KAGURU	**City/Town :** NKUBU
County : Meru	**District :** Imenti South District
Tax Area : Nkubu	**Station :** Meru
P. O. Box : 12	**Postal Code :** 60202

Tax Obligation(s) Registration Details

Sr. No.	Tax Obligation(s)	Effective From Date	Effective Till Date	Status
1	Income Tax - Company	11/05/2018	N.A.	Active

The above PIN must appear on all your tax invoices and correspondences with Kenya Revenue Authority. Your accounting end month is December unless a change has been approved by the Commissioner-Domestic Taxes Department. The status of Tax Obligation(s) with 'Dormant' status will automatically change to 'Active' on date mentioned in "Effective Till Date" or any transaction done during the period. This certificate shall remain in force till further updated.

Kenya Revenue Authority PIN Certificate.