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Seeds of Silicon: Internet of Things for Smallholder Agriculture

Anish Antony & Dan Sweeney

MIT D-Lab Comprehensive Initiative for Technology Evaluation (CITE)

Styvers Kathuni

SweetSense

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Introduction

Craig Jolley
Data Scientist, Center for Digital Development

Dan Sweeney
MIT D-Lab Comprehensive Initiative for Technology Evaluation

Anish Paul Antony
MIT D-Lab Comprehensive Initiative for Technology Evaluation

Styvers Kathuni
Regional Director for SweetSense

Agenda

- Welcome and Introduction – 5 min
- Report, IoT and Precision agriculture – 20 min
- Q&A – 10 min
- Sweetsense – Kenya Rapids Project – 10 min
- Q&A – 10 min
- Wrap up and Closing

How much do you know about IoT and Precision Agriculture?

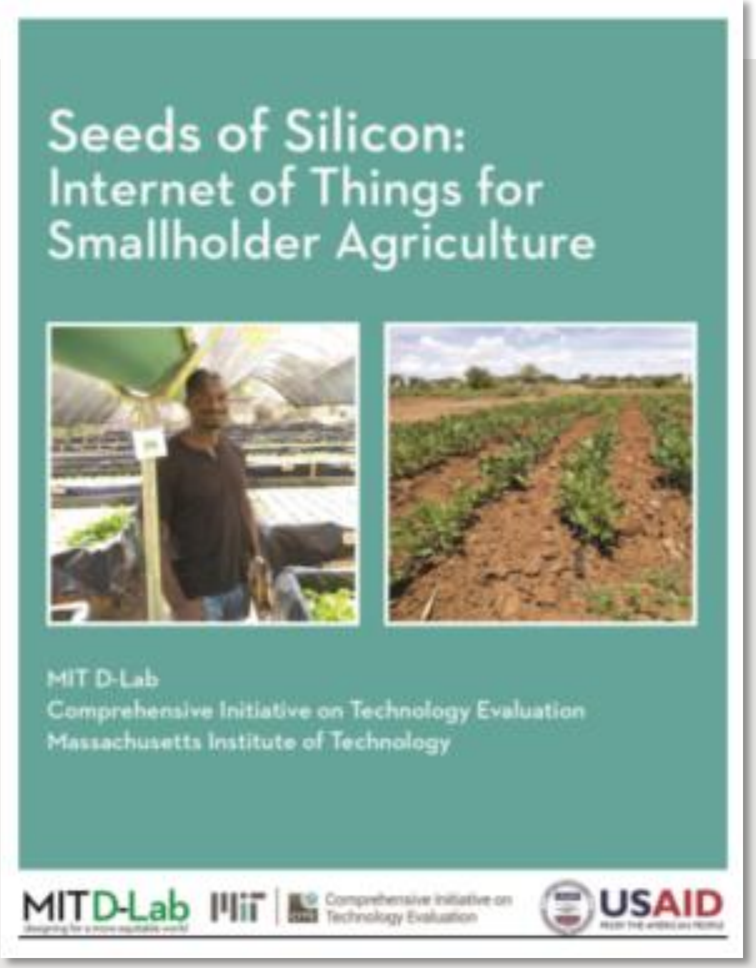
- Nothing – that's why I am here
- Only enough to wonder why everyone seems to be talking about it
- I am knowledgeable about IoT and Precision Agriculture
- I am an expert on IoT and Precision Agriculture

Outline

- IoT background
- Precision agriculture
- Research methods
- Challenges and Recommendations
- Implementation Examples
- Turkana borehole sensors case

What's in the report?

- Practical terms & definitions
- Current state of IoT in smallholder agriculture sector
- Research methods
- Challenges, opportunities & recommendations
- Sourcing Hardware Components
- Hands-on IoT training for students
- Data, Security, Privacy & Protection
- Implementation examples



Motivation

- 70% increase in food production needed to support Earth by 2050[1]
- Predictability and intuition decreasing due to climate change
- Connectivity increasing, cost of data decreasing, especially in developing countries[2]
- 25 billion networked devices worldwide[3]
- Precision agriculture is revolutionizing food supply in developed countries

[1]Agriculture; plantations; other rural sectors. (2018). Retrieved May 28, 2019, from https://www.ilo.org/global/industries-and-sectors/agriculture-plantations-other-rural-sectors/lang--en/index.htm
[2]FAO. (2009). How to Feed the World in 2050. FAO. Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEFÇ050_Global_Agriculture.pdf
[3]P. Biggs, J. Garrity, C. LaSalle, and A. Polomska, "Harnessing the Internet of Things for Global Development," 2016

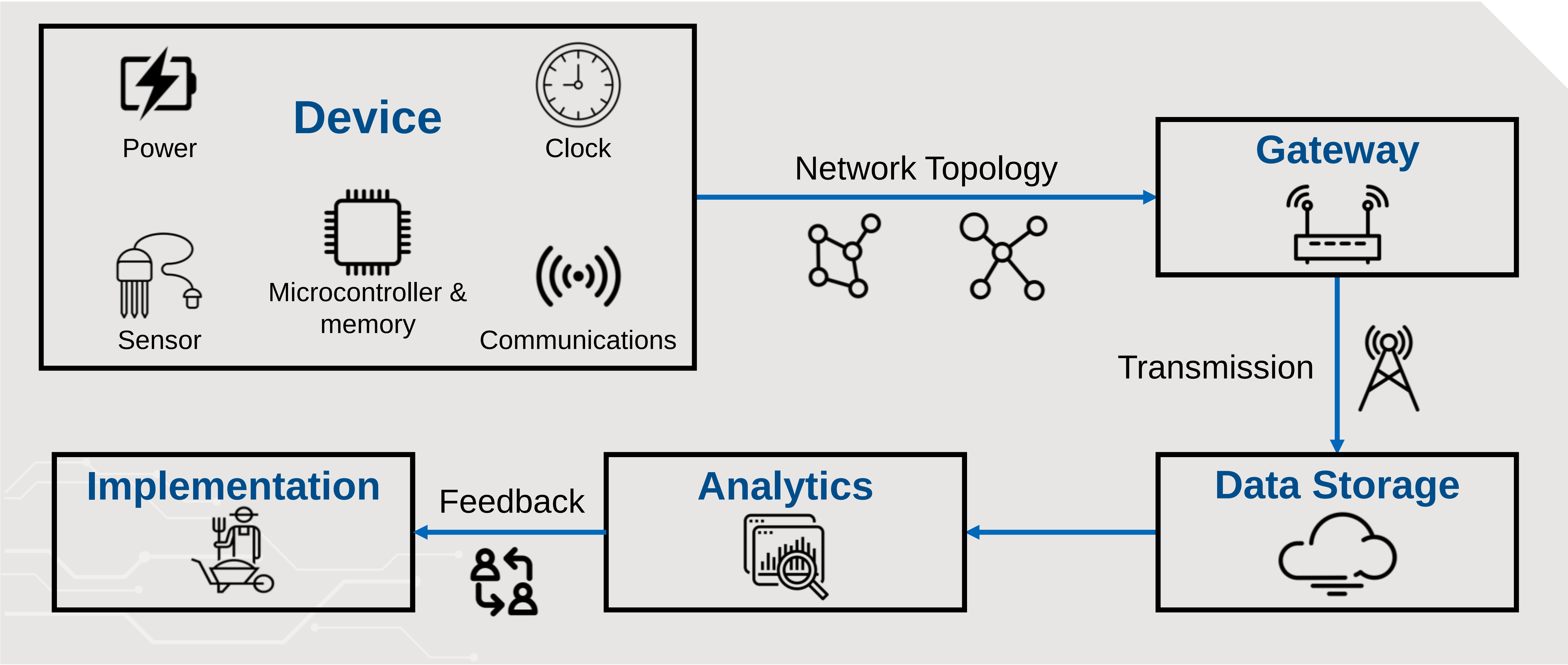
Internet of Things

"A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies"

ITU (2013). Next Generation Networks – Frameworks and functional architecture models. Overview of the Internet of things. Geneva: International Telecommunication Union. Retrieved from https://www.itu.int/rec/T-REC-Y.2060-201206-I/en

The first thing: CMU Coke machine 128.2.209.43 (Pittsburgh, USA, 1982)

IoT Infrastructure



Precision Agriculture

"A comprehensive system designed to optimize agricultural production by carefully tailoring soil and crop management to correspond to the unique conditions found in each field while maintaining environmental quality."

Blackmore, S. (1994), "Precision farming: an introduction", Outlook on Agriculture Journal, Vol. 23, pp. 275-280

IoT in Precision Agriculture

Soil

Moisture
Temperature
Nitrogen
Phosphorus
Potassium
pH

Plants

NDVI
Chlorophyll color

Atmospheric

Temperature
Humidity
Wind speed
Rainfall
Pressure

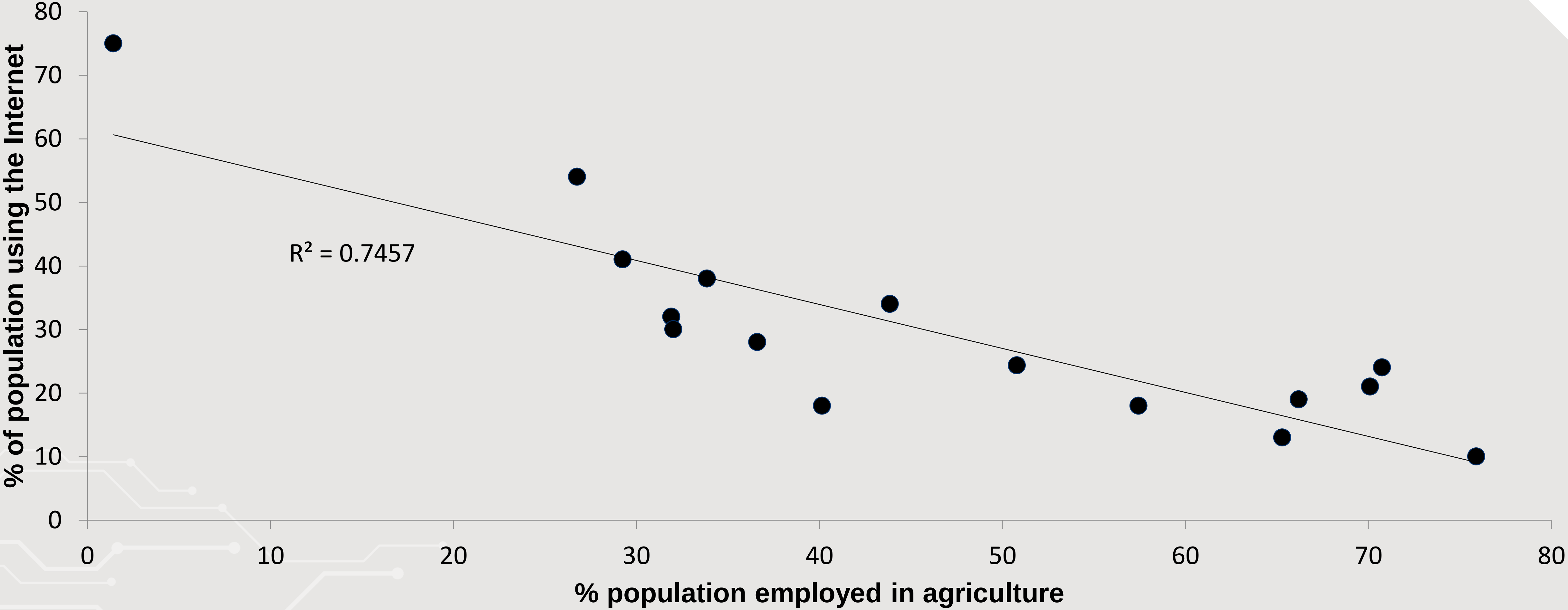
Water

pH
Temperature
Turbidity
Dissolved O_2

Other: optical milk quality

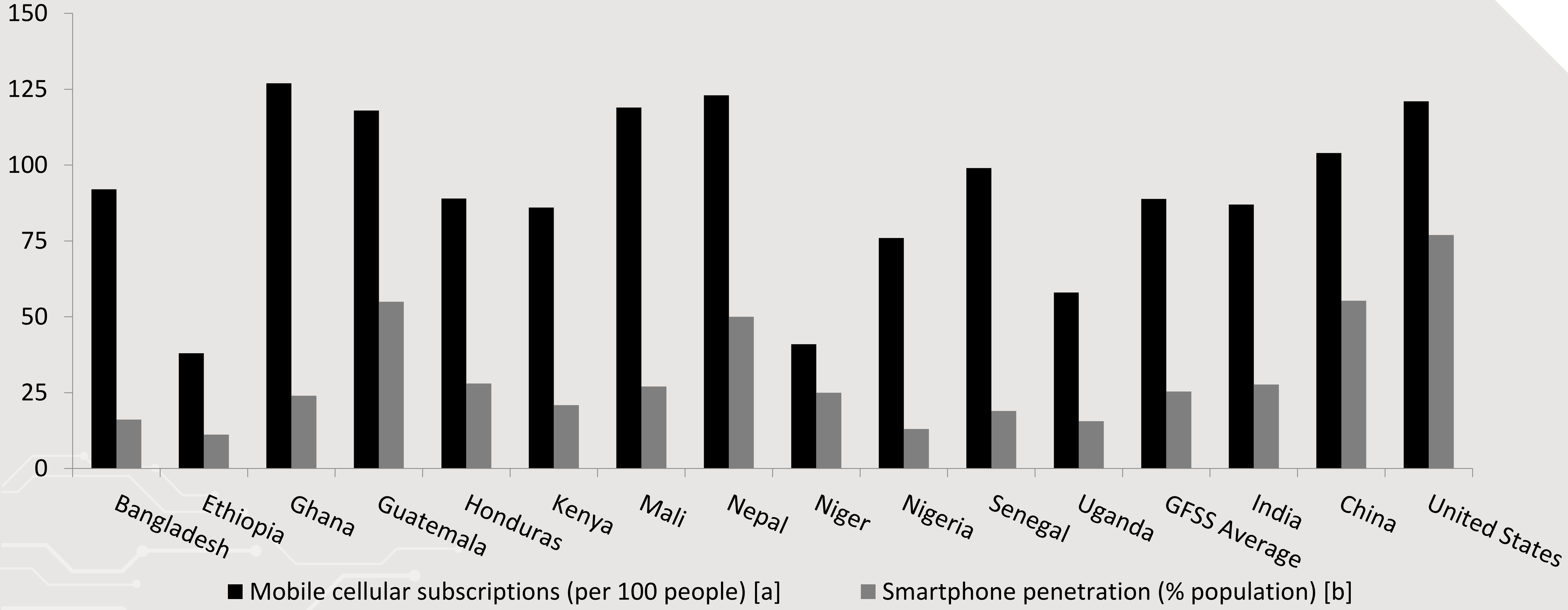
Farmer John and Anish at John's farm in Meru County (photo: Dan Sweeney)

Agriculture and internet usage



World Bank Data, data.worldbank.org

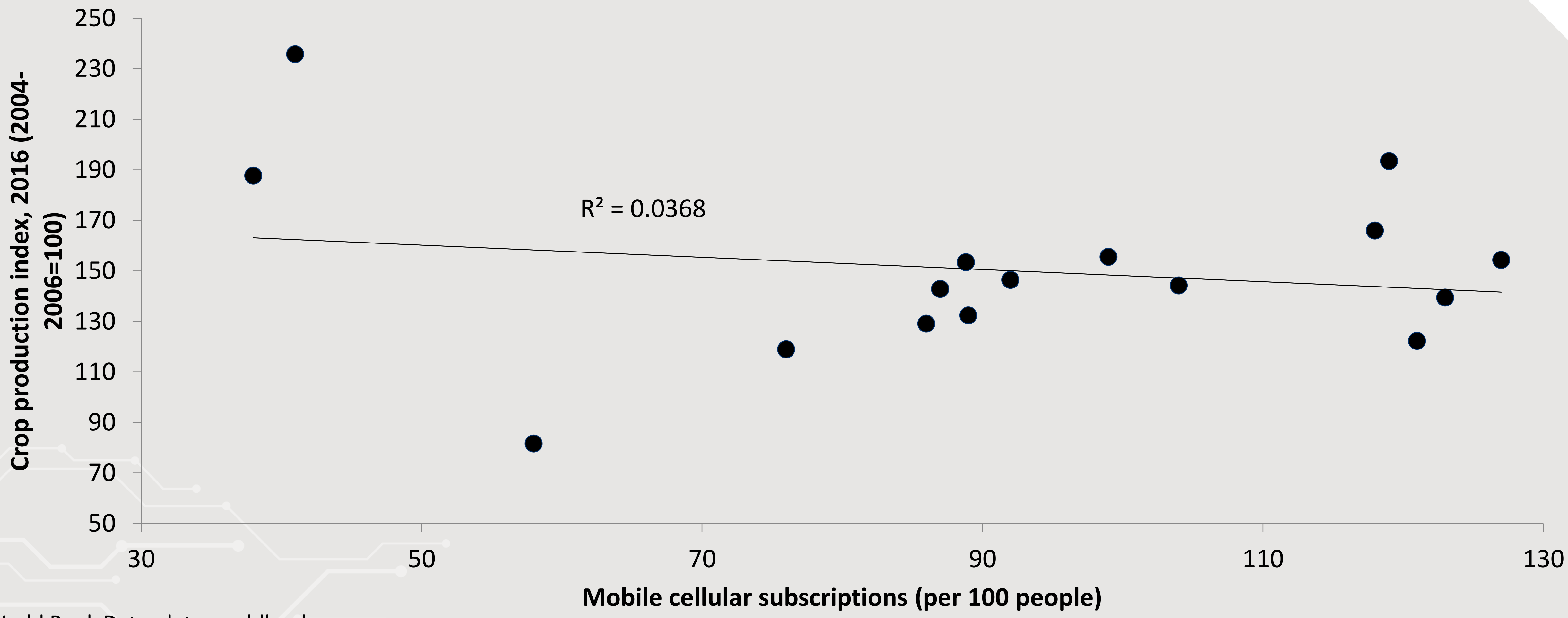
Mobile- and smartphone penetration



[a] World Bank Data, data.worldbank.org

[b] Newzoo, "Top 50 Countries/Markets by Smartphone Users and Penetration"

Crop productivity & mobile connectivity



World Bank Data, data.worldbank.org

Research Questions

- What is the current state of technology in agricultural sensors suitable for low-resource settings?
- What are the challenges to entry for low-cost sensors?
- What can implementers and funding agencies do to help overcome those challenges?
- How critical are concerns about equity of access, data privacy and data security?

Answer in the Chat box!

What kind of IoT application would be most useful in your work?

Research Methods

- Literature Reviews
- Stakeholder Interviews
- Surveys (2 sets)
  - Survey 1: US-based technology community working on sensors and precision agriculture
  - Survey 2: Agri-tech practitioners globally
- Site Visits: India and Kenya

Ag IoT in Kenya

IoT sensor type	Applications
Hall effect current sensor	Solar irrigation pump operation, water flow
Electrical conductivity	Soil moisture, pH
Thermistor, thermocouple	Air temperature, water temperature
Optical	NDVI, crop health
Sonar	Water level, grain level
UV	Irradiance

Communication protocol
Cellular
WiFi
Zigbee
Z-Wave
LoRa
BLE
SigFox LPWAN

Challenges

- Access to components
- Device Design
- Vertically Orient
- Funding Cycles
- Equity of Access and Data Security

Recommendations for Implementation Partners

- **Access to components**: Search at the local electronics repair and scrap market.
  - They can sell you basic circuit components

- **Device Design**: Install and run your device or close approximate at a pilot testing site

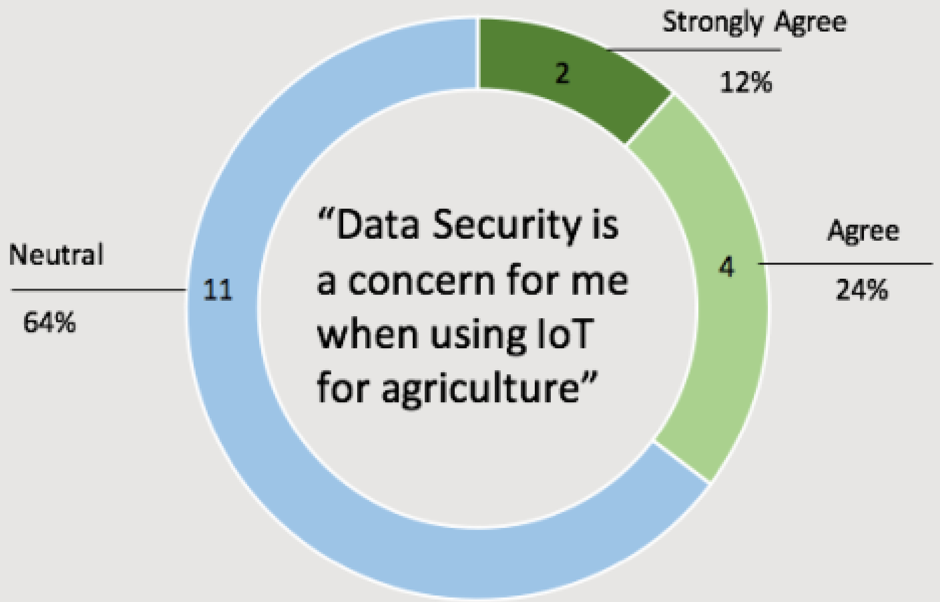
Arable Mark device with steel wires to deter birds from perching on the sensor (photo: Dan Sweeney)

Recommendations for Funder Agencies

- **Horizontal Orient**: Multiple organizations collaborate together
  - Explore opportunities for funding from areas such as the USAID BAA process
  - Donors like USAID, DFID, GIZ could help facilitate these connections
  - Donors could also establish a group similar to Gathering for Open Agricultural Technology group or Dutch Farm hack network
- **Funding Cycles**: Increase the timelines (5 – 7 years) of grant-funded projects

Recommendations for Implementers and Funders

- **Equity of Access**: Who does the data belong to?
- Smartphone apps – output reaches the intended audience in a format accessible to them



Data Security when using IoT in agriculture (Source: Survey of 17 respondents with direct experience in agriculture IoT projects)

Implementation Examples

Greenhouse environment monitoring

Mara River flood alert system

Climate and optical sensing

Micro-climate monitoring in aquaponics

Small-scale fish pond monitoring

Question & Answer Break

Acknowledgements:

- D-Lab: Dan Frey, Kendra Leith, Richard Ribon Fletcher
- Dorn Cox
- USAID: Craig Jolley, Katie Hauser, Maggie Linak, Ashley Faler, John O’Bryan

Practices from an Irrigation Project

Use of sensors for water point monitoring

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Who is SweetSense?

- **SweetSense** is a company that develops and deploys technologies to manage water and energy services in remote, off-grid environments.
- We monitor over 2 million people's water supplies in East Africa.
- In California, we are enabling farmers to comply with the Sustainable Groundwater Management Act.
- Borehole sensors are installed to link borehole pump functionality, water extraction rates and uptime data to an online dash board.

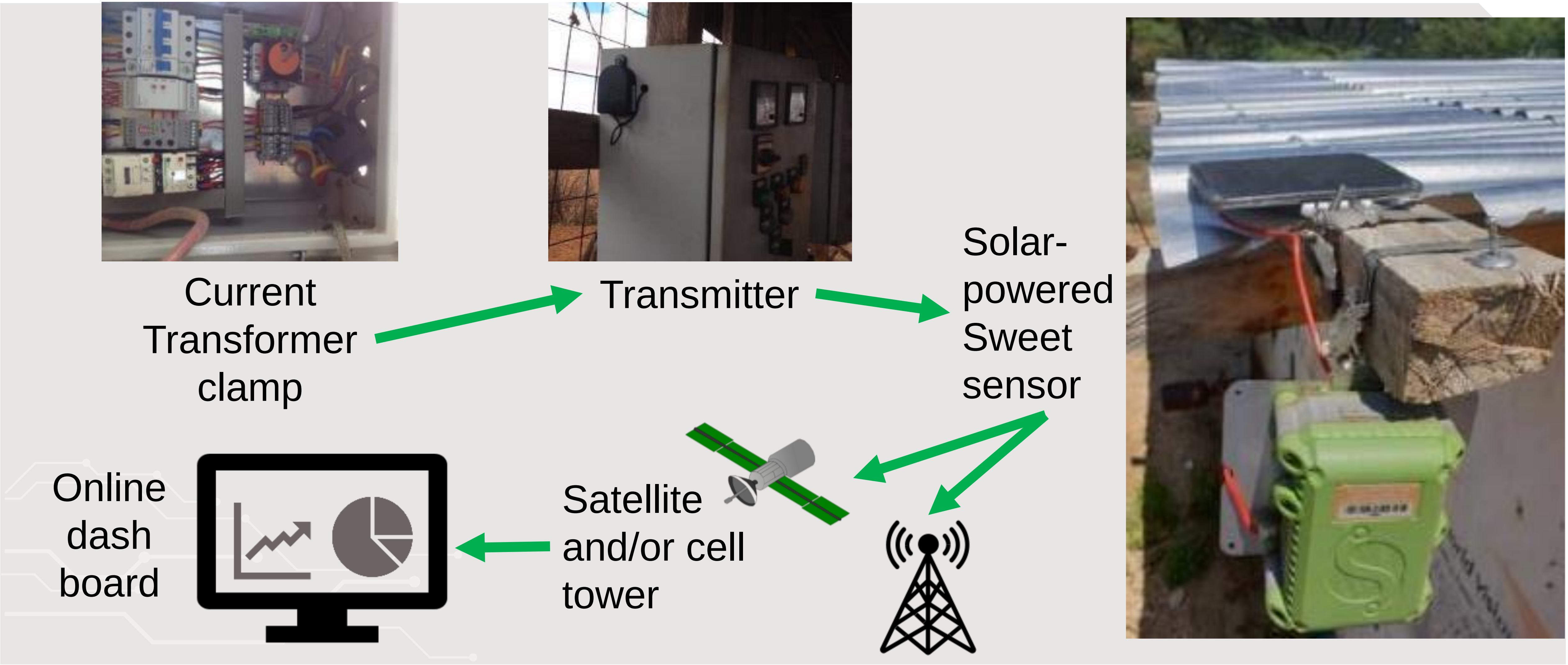
Components

Current Transformer clamp

Transmitter

Solar-powered Sweet sensor

How the technology works



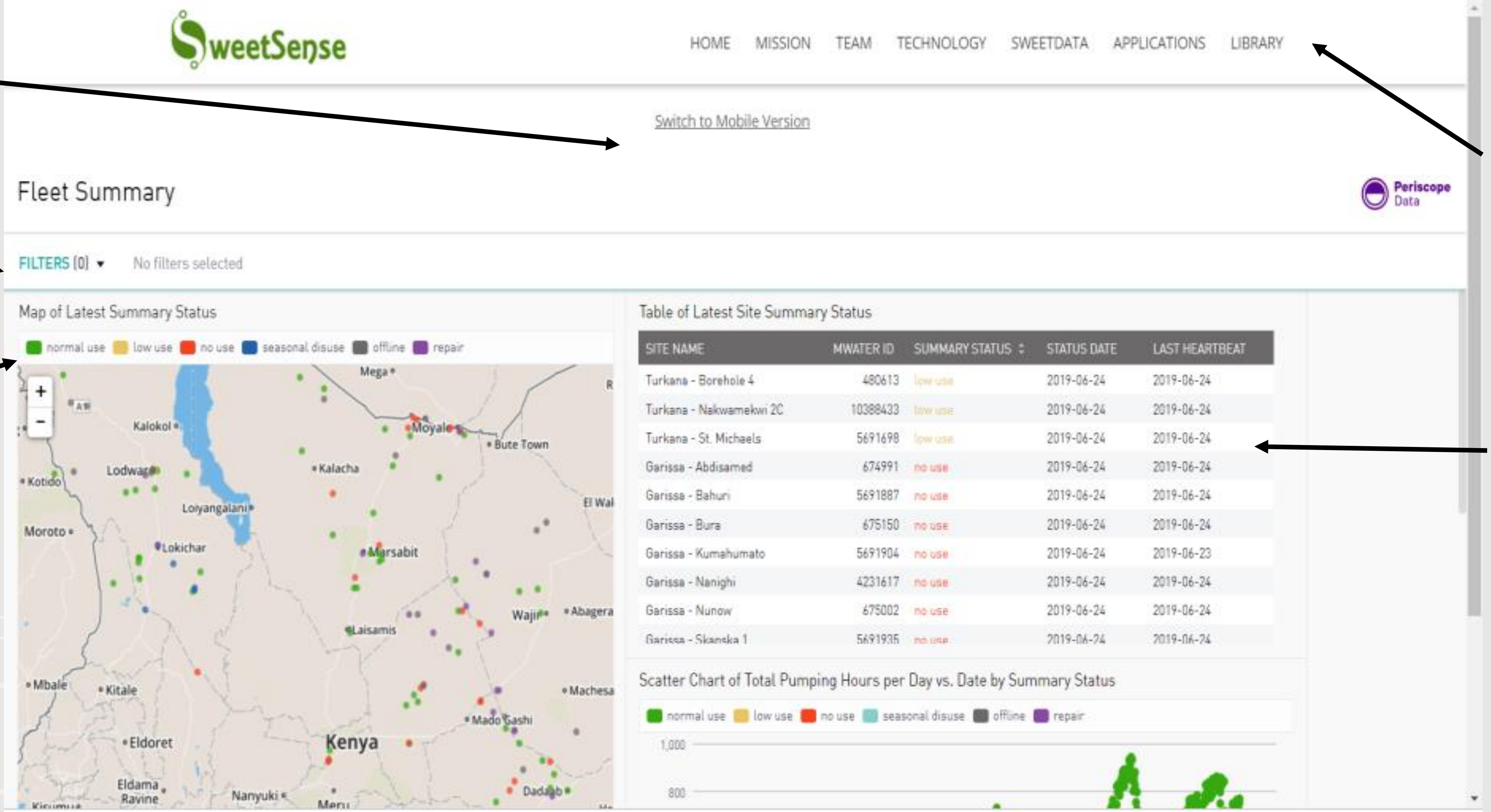
Dash board http://www.sweetsensors.com/sweetdata/kenyarapid/

Option to switch to mobile phone mode

Filters to refine search

Borehole status menu

Map showing location of sensors with zoom option



SweetSense company details

Borehole status table and reporting dates

Dash board continued

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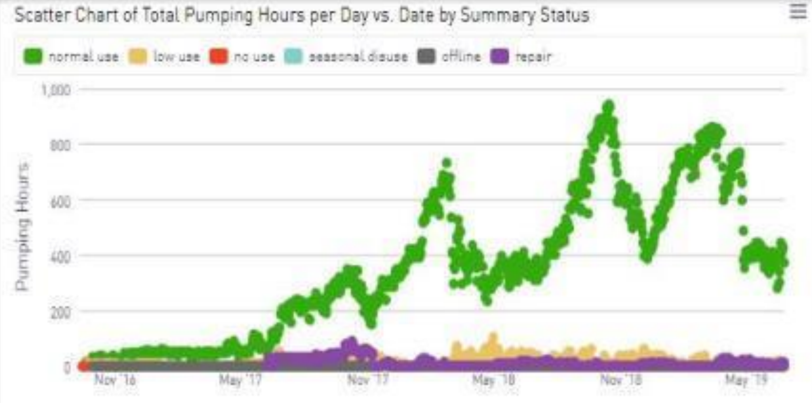
HOME MISSION TEAM TECHNOLOGY SWEETDATA APPLICATIONS



Graph; pumping hours, date and borehole status

Chart on number of sites vs borehole status

Daily Metrics (limited to the latest 1000 site-days)

SITE NAME	MWATER ID	LOCAL DATE	PUMPING HR	DAILY YIELD M3	HEARTBEAT	RAIN LAST WEEK
Garissa - Abakhaile	5691801	2019-06-24	0.0	0.0	1	
Garissa - Abdisamed	674991	2019-06-24	0.0	0.0	1	
Garissa - Alikune	674805	2019-06-24	0.7	16.7	1	
Garissa - Bahuri	5691887	2019-06-24	0.0	0.0	1	
Garissa - Baraki	5691911	2019-06-24	0.0	0.0	1	
Garissa - Bulla Benan	27240122	2019-06-24	0.0	0.0	1	
Garissa - Bura	675150	2019-06-24	0.0	0.0	1	
Garissa - Dertu	5691832	2019-06-24			0	
Garissa - Gurufa	674977	2019-06-24	8.0	64.0	1	
Garissa - Kitere	675088	2019-06-24	6.0	84.0	1	

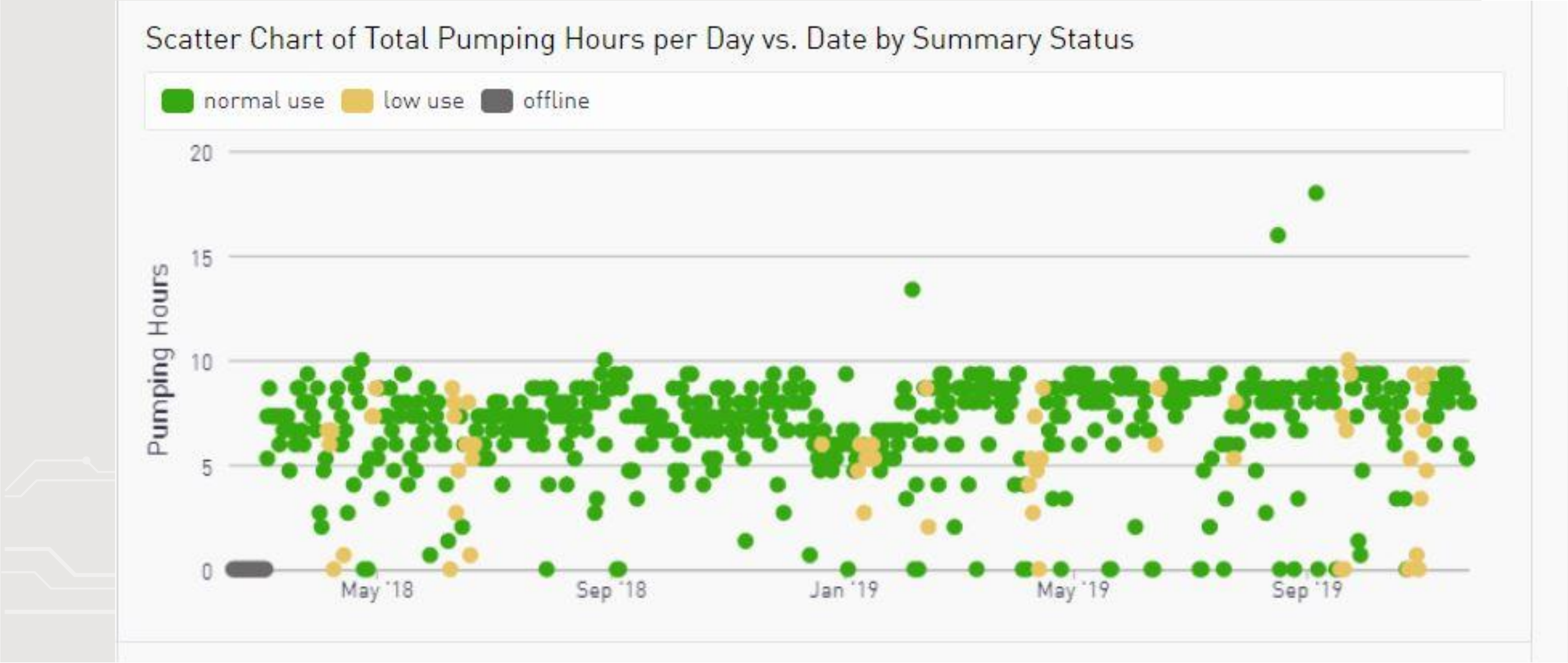
Table on pumping hours and quantity of water

Sensor inventory details

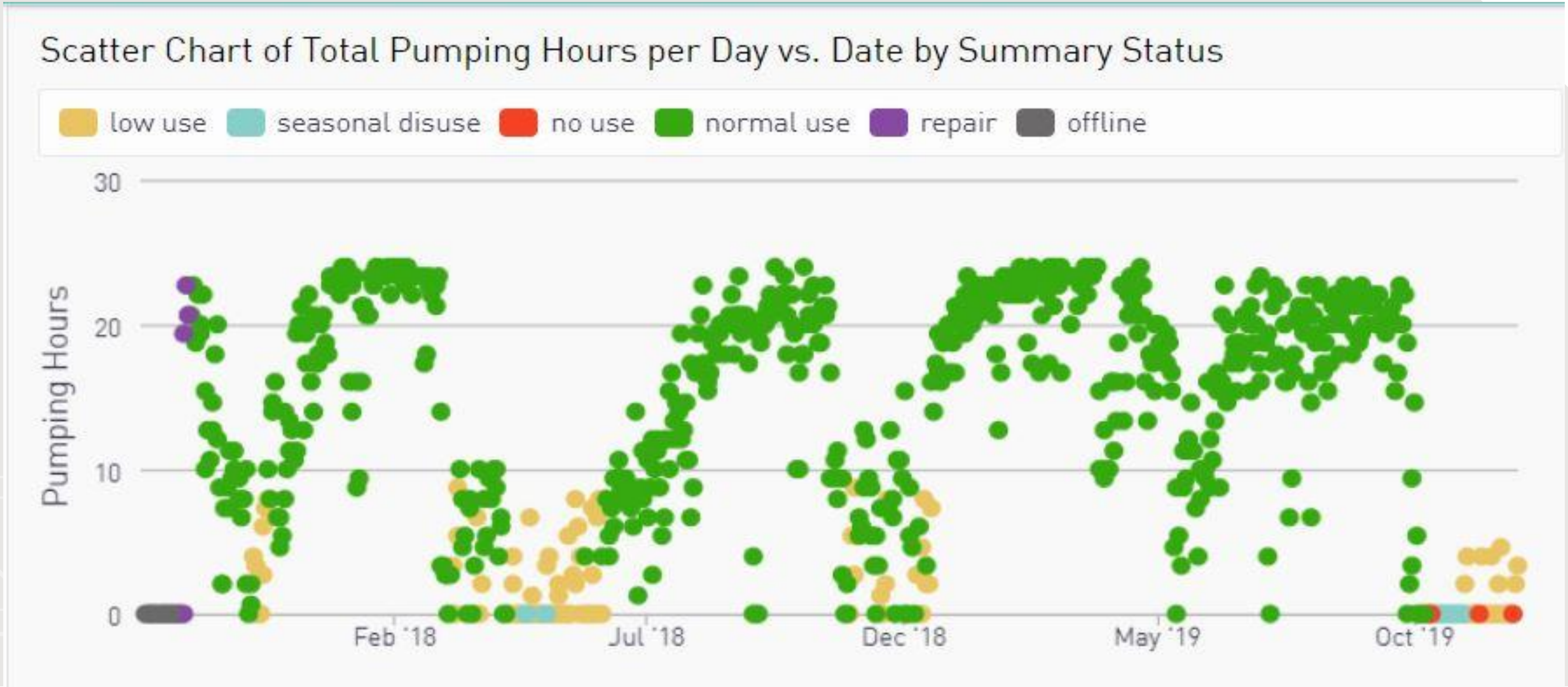
Installation Metadata

SITE NAME	MWATER ID	CUSTOMER	GATEWAY ID	GATEWAY BARCODE	INSTALL DATE	REMOVAL DATE
Garissa - Abakhaile	5691801	Kenya	POWER_SAT_300234064770530	6068	2017-04-28 00:00:00	
Garissa - Abdisamed	674991	Kenya	POWER_SAT_300234065693930	7510	2018-05-23 07:55:00	
Garissa - Alikune	674805	Kenya	POWER_SAT_300234064770520	6085	2017-04-28 00:00:00	2018-05-19 10:34:00
Garissa - Alikune	674805	Kenya	POWER_SAT_300234065893620	6107	2018-05-19 11:26:00	

Dash board continued



Dash board continued



Dash board continued

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SITE NAME	MWATER ID	LOCAL DATE	PUMPING HR	DAILY YIELD M3	HEARTBEAT	RAIN LAST WEEK
Turkana - Napuu 5	480699	2019-11-17	9.3	93.3	1	
Turkana - Napuu 5	480699	2019-11-16	8.7	86.7	1	
Turkana - Napuu 5	480699	2019-11-15	9.3	93.3	1	
Turkana - Napuu 5	480699	2019-11-14	8.0	80.0	1	
Turkana - Napuu 5	480699	2019-11-13	8.7	86.7	1	
Turkana - Napuu 5	480699	2019-11-12	9.3	93.3	1	
Turkana - Napuu 5	480699	2019-11-11	8.7	86.7	1	
Turkana - Napuu 5	480699	2019-11-10	8.7	86.7	1	
Turkana - Napuu 5	480699	2019-11-09	8.0	80.0	1	
Turkana - Napuu 5	480699	2019-11-08	7.3	73.3	1	

Installation Metadata

SITE NAME	MWATER ID	CUSTOMER	GATEWAY ID	GATEWAY BARCODE	INSTALL DATE	REMOVAL DATE
Turkana - Napuu 5	480699	Kenya	POWER_SAT_300234066002250	7187	2018-02-15 13:20:00	

Thank you

References

1. FAO. (2009). How to Feed the World in 2050. FAO
2. ICT sector statistics, (2012)
3. Z-Wave Explained, What is Z-Wave and why is it important for your smarthome (2018). Retrieved June 17, 2019, from https://www.the-ambient.com/guides/zwave-z-wave-smart-home-guide-281
4. 6LoWPAN vs ZigBee: Two Wireless Technologies Explained (2018). Retrieved June 15, 2019, from https://www.link-labs.com/blog/z-wave-vs-zigbee
5. Mekki, K.; Bajic, E.; Chaxel, F.; Meyer, F. (2018), “A comparative study of LPWAN technologies for large-scale IoT deployment.”, ICT Express, 5, pp 1-7