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坦桑尼亚农用无人机
DRONES FOR AGRICULTURE IN TANZANIA

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摘要

WeRobotics是一家总部位于美国和瑞士的非营利性组织，致力于促进南半球国家广泛参与新兴技术的普及和应用。通过不断扩大其地方知识中心——飞行实验室遍布非洲、拉丁美洲、亚洲和南太平洋的全球网络，WeRobotics不断推进无人机和人工智能等机器人技术在这些地区的本土化落地，从而弥合区域间的数字鸿沟。同时，WeRobotics还通过提供最佳实践范例和培训项目，助力社会公益，并在其构建的全球社区中进行知识共享。本文以WeRobotics在坦桑尼亚多多马地区的首个农用无人机项目为例，阐述了如何将相关技能和机器人技术传授给飞行实验室合作方，以及如何公开分享试点项目和最佳实践的经验，以塑造当地环境韧性及地区竞争力。

关键词

无人机；坦桑尼亚；小型农场；遥感；地面实况数据

ABSTRACT

WeRobotics is a young U.S. / Swiss based non-profit organization that builds inclusive participation and local capacity in the application of emerging technologies in the Global South. It bridges the digital divide by localizing robotics technologies like drones and artificial intelligence through its growing global network of local knowledge hubs — Flying Labs in Africa, Latin America, Asia, and the South Pacific, accelerating the social good sector through best practices and training programs and sharing knowledge through its global community. Taking WeRobotics' first drone agriculture project in the Dodoma region in Tanzania as an example, this article exemplifies how to transfer relevant skills and robotics technologies to Flying Labs' partners and openly share learnings of pilot projects and best practices to build local resilience and competencies.

KEY WORDS

Drone; Tanzania; Smallholder Farms; Remote-Sensing; Ground-Truth Data

翻译 李慧彦 田晓劼
TRANSLATED BY LI Huiyan TIAN Xiaojie

1 引言

如今，人们无需踏出国门就可以观测到地球上最偏远的地区。遥感技术的进步与人工智能（AI）分析的结合使我们能够对作物收成进行预测分析，并能够比过去更加准确、快速地模拟出气候变化带来的影响。虽然这些关于农场或海岸线的数据和预测能够为远程决策提供相关信息，但由于本土视角这一个关键要素的缺失，这些信息存在一定风险。

相比之下，无人机等小型自动化系统的使用天然具备本土性。这是因为无人机操控员必须亲自在现场进行操作，并与当地社区建立友好关系以获得必要的许可。因此，当地的无人机操控员通常具有本土化视角，并对本地情况非常了解。

通过使用无人机，人们能够以一种简单、经济且触手可及的方式随时随地获取大量本土数据——这也是无人机在地方实践中迅速普及的原因。结合其他数据源和AI 技术，通过无人机获取的数据不仅可以填补重要的数据空白，而且可以提供与数据相关的当地背景信息——这是远在千里之外运行的人造卫星所不具备的优势。

在经济发达国家，机器人和AI正从根本上改变其支柱产业的结构。总部位于美国和瑞士的非营利性组织WeRobotics一直致力于探索适用于低收入国家的机器人解决方案，以帮助推进当地的救援、医疗、开发和环境治理工作。试想，如果救援物资能够更快抵达灾区，偏远地区的病患能够得到及时的救治，“联合国可持续发展目标”可以更快实现，这些国家和地区将会发生怎样的变化？

WeRobotics基于不同的领域对项目进行分类[①]，生态机器人项目（EcoRobotics）即为其中一个类别。该项目力图构建最佳实践，并分享实践经验，为机器人技术在可持续农业、自然保育和可持续渔业中的应用提供适应当地需求的解决方案。空中机器人和水下机器人为解决当地社区问题创造了新的途径——人们可以利用机器人监测野生动植物和自然栖息地，从而更好地保护脆弱的生态系统，并为受气候变化影响的地区制定应对计划。机器人技术可以更高效地生成优质数据，协助当地合作方进行切实有效的分析，了解前沿信息，最终完成决策。

2 坦桑尼亚农用无人机项目

世界银行2014年和2016年的报告显示，全世界约80%的贫困人口居住在农村地区并主要依靠农业维持生计[1]。在非洲，约有80%的农场为面积约0.4~4hm^2的小型农场[2]。这些小型农场的农场主必须利用有限的土地资源生产、销售，并储存足够的粮食才能养家糊口。因此，联合国可持续发展目标的第二项即为实现“零饥饿”[3]，而减少农户的农作物损失能够极大提升全球粮食安全。同时，支持更加可持续的农业活动也是对可持续发展目标第15项——“陆地生物保护”的积极响应[4]。在此过程中，地理空间数据的使用可为打破粮食生产的重重限制提供一些思路。

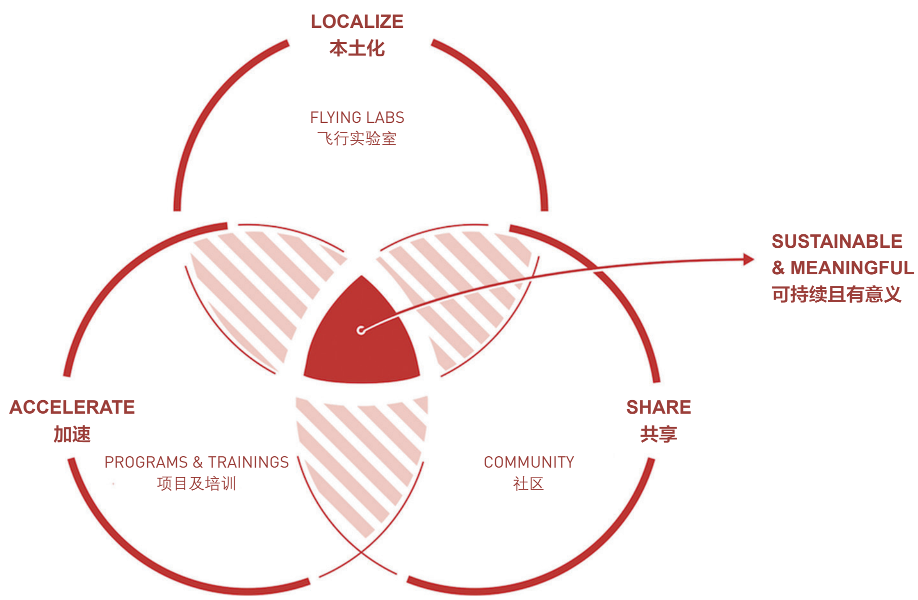
在与国际食物政策研究所（IFPRI）合作的一项研究项目中，WeRobotics在坦桑尼亚开展了该机构的首个农用无人机项目。IFPRI食物安全门户网站小组与收获联盟相互协作，后者是由美国国家航空航天局（NASA）委托成立、由美国马里兰大学牵头的新型跨学科联盟，旨在加强卫星数据在世界各地粮食安全与农业发展相关决策中的应用。收货联盟期望增强粮食安全与韧性，维持粮价稳定，提高不同领域的用户对NASA及其他卫星数据产品应用的认知和了解。利用卫星数据评估收获前的农作物损失需要在作物生长季收集详细的地面实况数据。而农场主对自有地块产量或（和）面积进行上报是当前评估作物产量的主要方法之一。

2017年末，IFPRI与WeRobotics进行接洽，试图寻找在坦桑尼亚开展试点研究项目的方案，试点项目旨在测评利用无人机验证卫星数据的可靠性。一旦该方法被证明有效，IFPRI将优先在坦桑尼亚当地寻找合作伙伴来共同探索可持续的落地方案。除了无人机采集的高分辨率航拍数据外，通过全球定位系统（GPS）获取的各区域测量数据以及小农场主上报的数据也有助于验证项目采集的卫星数据。

WeRobotics和作为其地方知识中心之一的坦桑尼亚飞行实验室热切希望针对该项目展开合作，发挥WeRobotics利用多光谱无人机数据对卫星数据进行地面实况普查的专业优势，以加强坦桑尼亚当地社区参与此类项目的能力。作为2017年举办的坦桑尼亚飞行实验室“无人机作为服务设施”企业孵化项目的决赛团队之一，Agrinfo的研发方向恰好是农用无人机。基于此，WeRobotics向IFPRI和马里兰大学提议与坦桑尼亚飞行实验室及Agrinfo合作，组建一支多元化的团队，各施所长共同攻克这一富有挑战性的项目。团队采集了用于创建归一化植被指数（NDVI）[②]的多光谱数据以及基于GPS测量的小型农场边界数据，并通过调研获得其他农户数据。合作各方一致认为在农作物生长周期内进行两轮数据采集较为理想，即在花期之前和收获之前各采集一次。项目重点关注多多马地区北部的申巴区，这里是坦桑尼亚农村和边远小型农业的代表性区域。

2018年3月初，一个由IFPRI、WeRobotics和Agrinfo项目负责人、无人机操控员、GIS专家及实习生、测绘员和司机组成的11人团队，在申巴区的三个村庄内进行了为期5天的首轮数据采集工作，内容主要包括与当地社区的接洽、目标区域的确定，以及数据采集。通过与当地官员、农业社区负责人以及小农场主进行交谈，团队进一步了解了当地所面临的挑战。除了收获前的农作物损失，如何对产量进行更为准确的估算也是一大难题。在讨论过程中，团队发现很多小农场主并不清楚自家农场的准确面积，常常高估或低估农田的大小，这一基本判断的缺失也会导致产量的误判。

在农场的第一天，团队即确定了试点项目的初始范围，并将这一轮收集的地理空间数据作为第二轮数据收集工作的基础，其中包括与当



1 © WeRobotics

1. WeRobotics的核心能力及优势

1. Key abilities or strengths that WeRobotics has developed

① WeRobotics基于不同领域项目构建最佳实践范例，包括救援机器人项目（AidRobotics）、医疗机器人项目（HealthRobotics）、开发机器人项目（DevRobotics）和生态机器人项目（EcoRobotics）。这些项目分别与飞行实验室的救援、公共卫生、开发机构和环保组织合作。在技术合作方的支持下，各飞行实验室可与其联合开展项目。

② 归一化植被指数是一种简单的图形指标，通常（但不一定）来自太空观测平台，可用于分析遥感观测结果，并评估观测目标是否包含绿色植被。

2 © WeRobotics

3 © WeRobotics

地小农场主确认的农场边界信息。首轮数据采集的另一个重要收获是确定了一个经常被忽略的影响因素：天气情况。在坦桑尼亚，农作物的生长周期和雨季直接相关，而雨季的云量对于抵达偏远农村地区、操纵无人机进行数据采集，以及获取实时卫星数据都会构成挑战。以上发现均表明试点项目的重点不仅在于确定项目范围，更在于进一步了解项目的潜在风险。尽管天气条件欠佳，团队仍然收集到了4个目标区域（面积为50~800hm^{2}不等）的多光谱无人机数据、100多条农场边界数据、农作物类型，以及每个农场的历史产量情况。

同年5月初，团队进行了第二轮数据采集，不仅从中了解到了更多内容，更将相关经验运用于采集和处理海量高分辨率航拍数据和农场边界数据的过程中，并在社区参与方面投入了更多精力。团队将第一次实地考察后绘制的地图和农场边界图分享给三个目标村庄的农民和官员。通过与当地利益相关方进行讨论，团队充分了解了他们的需求，以进一步分析高分辨率航拍数据是否能满足这些需求。通过两轮数据采集，团队收集到了300余名小农场主的信息。之后，马里兰大学和IFPRI开始对采集到的全部数据进行深入分析和匹配，以推断将卫星和无人机数据相结合能否有效避免收获前的农作物损失。

在两轮数据采集过程中，团队面临的最重要的挑战是：

1）模糊的农场边界：为了计算产量，首先应确定农场规模。由于农场边界难以通过数字技术获取，因此需要与当地农民一起，手持GPS设备沿农场边界步行进行测量。

2）非标准度量单位：调查期间，农场主自行上报的土地面积也被考虑在内。然而，团队很快意识到当地农民会混淆“英亩”和“公顷”这两个单位。此外，在步行测量农田时，农民有时会错将70英尺见方等同于一英亩。

3）间作：虽然研究工作最初只关注玉米这一种作物，但团队在实地考察期间发现当地普遍实行间作。由于一种作物的光谱信号会被其他作物的光谱信号干扰，所以间作将直接影响研究结果。

关于无人机数据和地面实况数据，团队了解到以下几个重点：

1）完整性：在数据处理过程中，团队发现实际收集数据的质量并未达到预期。最终收集到的三种数据分别是访谈调查数据、通过GPS获得的农场边界数据，以及无人机图像数据。后两者有时无法被完全收集到，特别是当农民在家中接受采访而未能与调查员一起在农场收集边界数据的情况下。

2）准确性：每个农场所收集的数据都必须经过人工整理和修正。

3）一致性：无人机图像采集和访谈调查分多次进行。在某些情况下，对于同一处给定的农场地块，不同的受访者会反馈不同的信息，这些信息需要进一步修正以确保数据的一致性。

3 结语

如何利用无人机解决小农场主所面临的迫切挑战？WeRobotics认为，为之探索出一套可持续的实操方案至关重要，该方案应该与当地基础设施、数据获取成本，以及它为当地农业价值链所创造的价值相适应。非洲联盟于2018年2月公布了一项决议，要求联盟及其成员国应用包含农用无人机在内的三项相关新兴技术以促进非洲的发展，这使得相关国家对技术本土化的需求愈加迫切。尽管该项决议带来了大量机遇，但将当地需求、环境和价值链纳入解决方案的考量之中仍然至关重要。

技术只是达成目标的手段。通过推动无人机和AI等机器人解决方案的普及，以使更多人学习如何将这些方案更为安全、负责任，且有意义地用于提升社会福祉，将促成多方共赢。WeRobotics将不断向各个飞行实验室传授相关技能和机器人技术，以努力打造全球性合作社区，并向世界各地的相关人士公开分享试点项目和最佳实践的经验以不断增强本土力量的影响力，从而更好地保护我们的美丽星球和星球上的生物。**LAF**

2. 正在小型农场中劳作的妇女
3. 在坦桑尼亚农村地区开展无人机数据获取工作
4. 在坦桑尼亚飞行实验室试点中，尤索夫正在发动一架固定翼无人机，以为一个当地农业研究项目收集数据。

2. Women laboring their smallholder farms
3. Setting up for drone data acquisition in rural Tanzania
4. In Tanzania Flying Labs pilot project, Yussuf was launching a fixed-wing drone for data acquisition for an agriculture research project in rural Tanzania.

1 Introduction

Today, even the most remote areas of our planet can be observed without the need to ever set foot on foreign land. Advances in remote sensing combined with the analysis by Artificial Intelligence (AI) allow us to run predictive analytics on crop harvests and model the impact of climate change more precisely and quickly than ever before. While such data and forecasts can help inform better decisions thousands-of-miles away from the farms or the coastline, they run the risk of missing one critical element: the view from below.

In contrast, the use of small autonomous systems like aerial drones is necessarily localized. A person has to be physically present and engaged with his / her local community to secure the necessary permissions when using drones. Therefore, local drone operators always have the view from below, capturing the local context along with local idiosyncrasies.

The use of drones enables people to acquire a host of local data where and when they need it, in an easy, affordable, and accessible way. This explains why drones are becoming more pervasive in local initiatives. Combined with other data sources and AI to support analysis, drone data not only fills an important data gap but also connects contextual information linked to the data — an advantage lost on satellites orbiting our planet thousands of miles away.

Robotics and AI are radically transforming major industries in the world's richest countries. The mission of WeRobotics, a young U.S. / Swiss based non-profit organization, is to sustainably localize appropriate robotic solutions in low-income countries to accelerate the positive impact of aid, health, development, and environmental efforts. What if aid could reach affected communities more quickly? What if the health needs of remote communities could be met more rapidly? What if the Sustainable Development Goals (SDGs) could be achieved faster?

EcoRobotics Program, one of the sector-based programs at WeRobotics①, seeks to build best practices, share lessons learned, and localize appropriate solutions for the application of robotics in sustainable agriculture, nature conservation, and sustainable fisheries. Aerial and underwater robotics are creating new ways to support local communities, enabling them to better protect their fragile ecosystems by monitoring wildlife and natural habitats and plan for environmental impacts in areas affected by climate change. Robotic technologies give local partners new tools they need to generate better data in more effective and efficient ways, leading to actionable analysis and timely insights for decision-making.

4 © WeRobotics

2 A Drone Agriculture Project in Tanzania

According to World Bank's reports of 2014 and 2016, almost 80 percent of the world's poor people live in rural areas and rely primarily on agriculture for their livelihoods[1]. In Africa, around 80 percent of all farms are small-scale farms between 1 and 10 acres[2]. From these farms, farmers need to produce, sell, and store enough of their production to be able to feed their families. Reducing crop loss in rural households could greatly support global food security under the United Nations' Sustainable Development Goal 2 — Zero Hunger[3] and supporting more sustainable farming practices also influences Goal 15 — Life on Land[4]. The use of geospatial data allows insights to address constraints to production.

WeRobotics' first drone agriculture project in Tanzania is in partnership with a research project conducted by the International Food Policy Research Institute (IFPRI). IFPRI's Food Security Portal team is a partner of Harvest, a new and multidisciplinary program commissioned by NASA and led by the University of Maryland (UMD) to enhance the use of satellite data in decision making related to food security and agriculture domestically and globally. Harvest's goals include increasing food security and resiliency, reducing price volatility, and improving awareness and understanding of the applications of NASA's and other satellite data products by users from a wide range of sectors. The pre-harvest loss assessment using satellite data requires the collection of detailed ground-truth data

① WeRobotics creates best practices through sector-based programs — AidRobotics, HealthRobotics, DevRobotics and EcoRobotics. These programs partner Flying Labs with aid, public health, development and environmental organizations respectively and with technology partners to carry out joint activities in each Flying Lab.

over the growing season. One of the main empirical methods to measure ground-based yield is based on farmer-reported measures of either production or plot area (or both).

In late 2017, IFPRI approached WeRobotics to find a localized solution in Tanzania for their pilot research project that seeks to evaluate a new method for validating satellite data using drones. For IFPRI, finding local partners in Tanzania was a prerogative in order to have a sustainable solution for the future if this new method was proved effective. In addition to acquiring high resolution aerial data, GPS-based measure of areas and a self-reported survey of smallholder farmers help verify the data collected on this project.

WeRobotics and one of its local knowledge hubs — Tanzania Flying Labs were keen to partner on this project to build expertise in using multispectral drone data, which could help acquire ground-truth satellite data. The main goal is to contribute to building up local capacity in Tanzania to engage in such projects. Agrinfo, one of the finalist teams of Tanzania Flying Labs' "Drone as a Service" Business Incubation Program organized in 2017, happened to be specializing in drones for agriculture. WeRobotics proposed to IFPRI and UMD a collaboration between WeRobotics, Tanzania Flying Labs, and Agrinfo, each bringing their expertise and creating a diverse team to tackle this challenging project and acquire both multispectral data to create Normalized difference vegetation Index (NDVI)[②] as well as GPS-based boundary measures of smallholder farms and additional household data acquired by a survey. The partners agreed that two rounds of data acquisition during the growing cycle would be ideal — one just before flowering and the other before harvest. The focus was set on Chemba District in the northern part of Dodoma region, a representative area of both rural and remote smallholder farming in Tanzania.

In early March 2018, a team with 11 members including project leaders from IFPRI, WeRobotics, and Agrinfo as well as drone pilots, GIS experts and trainees, surveyors, and drivers spent five days in three villages of the Chemba district. The main focus of this first round of data acquisition was local community engagement, decision on areas of interest and data acquisition. By speaking to village officials, local leaders of the farming community as well as the smallholder farmers, the team were able to learn more about their challenges. While pre-harvest loss is one challenge, so is better estimation of yield. In the discussions, the team learned that many smallholder farmers did not know the exact size of their farms and often over- or underestimate their sizes. This important basic issue can also have an influence on wrong expectation of yield.

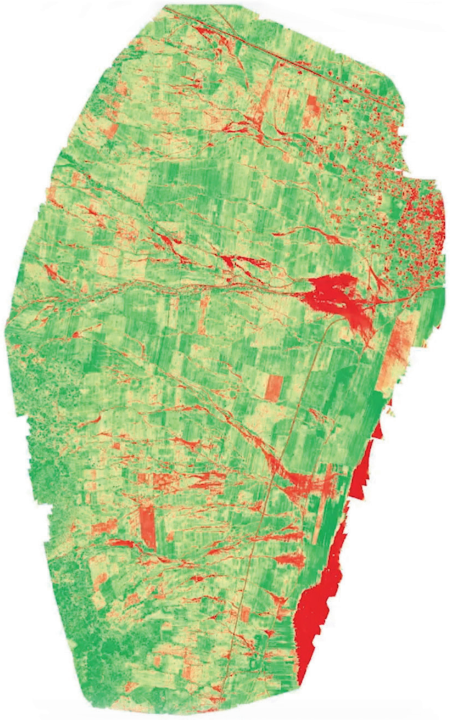
In the first day out in the fields, the team were able to confirm the initial scope of the pilot project and to use the acquired geospatial data as a base for the second round of data acquisition including the validation of the boundary information with the local smallholder farmers. Another important learning during this first round of data acquisition was the confirmation of a basic fact that is overlooked most of the time: weather. In Tanzania, growing cycles are directly linked to the rainy season

② The Normalized Difference Vegetation Index (NDVI) is a simple graphical indicator that can be used to analyse remote sensing measurements, typically, but not necessarily, from a space platform, and assess whether the target being observed contains live green vegetation or not.

5 © WeRobotics

5. 团队成员实地考察并收集现场的地面实况数据
6. 通过2018年采集到的数据，团队创建了归一化植被指数（NDVI）图像并绘制了农场边界图。

5. Field surveying and ground-truthing during the on-site data collection
6. Normalized difference vegetation index (NDVI) and farm boundaries were created out of the data collected in 2018.



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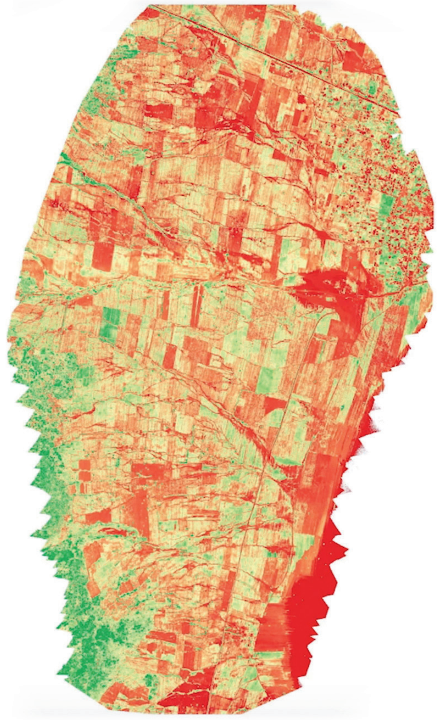

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which makes accessing remote rural areas, flying drones to acquire data as well as having timely satellite data disturbed by cloud cover challenging. Both these learnings show the importance of pilot projects to validate not only project scopes but also to learn more on possible project challenges. Despite the difficult weather conditions, the team were able to collect multispectral drone data of 4 areas of interest, ranging from 50 hectares to 800 hectares as well as data of over 100 farm boundaries and information on the type of crop as well as yield history of each farm.

In early May 2018, the second round of data acquisition allowed to add more learnings to the process of acquiring and processing amounts of high resolution aerial data and farm boundary data. More time was spent in engaging with communities during this trip. The team brought back the maps and farm boundaries produced after the first field trip and shared them with the farmers and officials of the three villages investigated. Thanks to the discussions with local stakeholders, the team learn more about their needs to find ways of how high resolution aerial data can, or cannot, address them. Two rounds of data acquisition allowed the team to collect information of over 300 smallholder farmers. Since then, UMD and IFPRI have been conducting in-depth analysis to match all the acquired data to understand if satellites and drones in combination can become a viable and more efficient method to address pre-harvest loss.

Most important challenges faced during these two rounds of data acquisition have been:

1) Invisible farm boundaries: In order to calculate yield, determining farm sizes was a priority. However, this exercise had to be done by physically walking the farms' boundaries with farmers and handheld GPS mainly because the boundaries are not well defined for the exercise to be done digitally.

2) Non-standard metric: During the survey, the respondent self-reported land area was taken into account. However, the team quickly realized that there was confuson between acre and hectare and that farmers did measure their farm plots by walking 70 feet wide and 70 feet long and then equated it to an acre.

3) Intercropping: While the team's work initially focused on Maize, extensive intercropping was discovered during the field work, impacting directly the analysis results as the spectral signal for each individual crop mighe be obfuscated by other crops.

The team has also made following important learnings in relation to the drone data and ground-truthing data:

1) Completeness: During the data processing, it was found that there was a gap between what was expected and what was collected. Three kinds of data collected were interview- survey data, farm boundary with GPS, and drone data. The latter two types of data were not always completed especially in cases that the farmer was interviewed at the household and failed to meet up with the enumerator on the farm plot to complete the farm boundary data collection.

2) Accuracy: For every farm, three kinds of data mentioned above were collected and had to be manually aligned.

3) Consistency: The drone imagery as well as the interview survey was done multiple times and there have been cases where for a given farm plot, different respondents gave different information which needed alignment.

3 Conclusion

WeRobotics believes it is of highest importance to find answers and solutions to how drones can address the pressing challenges of smallholder farmers in a sustainable, viable, and meaningful way that is adapted to local infrastructure, local cost of data, and the value it can create for local farming value chains. Such localized learnings are also urgent as the African Union (AU) published a decision in February 2018, requesting the AU and its member states to harness drones for agriculture as one of three emerging technologies of relevance for African development. While this decision opens up many opportunities, it is important for solutions to take into account the local needs, context, and value chains.

Technology is always only a means to an end that everyone wins by democratizing access to robotics solutions such as drones and AI and the knowledge to apply these solutions safely, responsibly and meaningfully for social good. WeRobotics will continue transferring relevant skills and robotics technologies to Flying Labs, facilitating a global community to partners, and openly sharing learnings of pilot projects and best practices with all national and international stakeholders to keep on creating impact through the power of local, so they can better protect our beautiful planet and life on land and underwater. **LAF**

7. 在当地农民的配合下，项目团队完成了数据收集工作，并利用这些数据制作了一系列地图和农场边界图面向公众公开展示。

7. Project team was sharing maps and farm boundaries produced after data acquisition with the farmers.

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