NJALA UNIVERSITY PROPOSAL

INCORPORATING DRONE-DRIVEN HOUSE RISK PREDICTION SYSTEMS FOR COST-EFFECTIVE VECTOR CONTROLS IN SIERRA LEONE

NATIONAL SCIENCE, TECHNOLOGY AND INNOVATION COUNCIL (NSTIC) – SIERRA LEONE;

THEME AREA 4: NEW AND EMERGING TECHNOLOGIES

17 OCTOBER, 2023

1. EXECUTIVE SUMMARY

Malaria is an important cause of illness and death in people living in sub-Saharan Africa, and it also remains one of the biggest public health challenges in Sierra Leone. Malaria is the leading cause of mortality among infants under 5 years of age and accounts for almost half of all outpatient cases of all ages, putting strong pressure on the country's healthcare system and financial base. The Government of Sierra Leone has continued to invest heavily in malaria control following the Sierra Leone National Malaria Elimination Strategic Plan. The country has made tremendous strides to delineate the efforts required to control the impact of malaria among its citizens, and the number of malaria cases and deaths are declining at appreciable rates. However, the strong reliance on international donors and Non-Governmental Organizations (NGOs) have created significant financial sustainability challenges, and the government now encourages cost-effective interventions to mitigate against the effects of malaria.

Also, there is growing concern that climate changes have huge influences on the ecology of mosquitoes. A serious problem in the African continent is the threat of Anopheles Stephensi, which was initially identified with Asia but recently confirmed to be in Western African countries, such as Nigeria and Ghana. Therefore, up-to-date monitoring of such unprecedented shifts of mosquito entomology in Sierra Leone, on the premise of maximization of cost-effectiveness intervention strategies, is significant, as mentioned above.

To deal with these issues in cost-effective ways, modern surveillance systems for entomology and new technologies have been utilised, such as drones, machine learning, big data, and citizen science. These innovative strategies can be combined with present tools to better understand mosquito population dynamics and determine areas that might be at risk. In particular, such a model can be used for evidence-based decision making in endemic areas of mosquito-borne diseases such as malaria for more efficient, targeted vector control logistics designs.

The proposed study involves a multidisciplinary research design that combines drone-based mapping, satellite-based observations, Using Artificial Intelligence, entomological field surveys, and algorithm development, we aim to identify new index named “infectious risk index” for many houses targeted, by examining multiple factors, including the physical/environmental conditions of the houses and the distribution data of puddles with a high likelihood of mosquito breeding environments. In the proposed study, it is expected that communities and houses which are prone to mosquito invasion are predicted precisely, so that preliminary vector control countermeasures will be identified and implemented.

2. BACKGROUND AND RATIONALE

Sierra Leone has a long history of experiences with the mosquito-borne diseases centered on malaria. Despite the huge progress toward malaria elimination in the last decades, Sierra Leone has been ranked among the highest malaria-endemic countries globally, with over 7.5 million at risk of malaria infection(Koroma et al., 2022) and malaria being the leading cause of death in most age groups (Carshon-Marsh et al., 2021). This burden has a significant economic impact on the country, leading to decreased productivity and increased healthcare costs. The transmission of malaria in Sierra Leone is high as the country has the climatic conditions for mosquito breeding. The hot, humid climate and inadequate sanitation and water supply provide ideal breeding grounds for the two main species of malaria-carrying mosquitoes (Anopheles gambiae and Anopheles funestus). Additionally, most people in Sierra Leone do not appropriately utilize mosquito nets, and have less access to environmental control programs such as mosquito fumigation or insecticides, and preventative medications (Ansumana et al., 2020; Koroma et al., 2022).

Over the years, various strategies have been implemented to eliminate malaria disease (Fombah et al., 2023; Ishizumi et al., 2021; McCoy et al., 2021). The strategies include using insecticide-treated bed nets and Indoor Residual Spraying (IRS). Despite these interventions, the malaria situation remains dire in Sierra Leone. Furthermore, the implementation of larval source management (LSM) has been undertaken. However, due to budget constraints for vector controls, the number of districts where IRS has been implemented is limited, and there is no budget identified for LSM.

In order to pursue the global agenda to eliminate malaria and other mosquito-borne diseases by 2030, cost-effective innovative tools have been identified that enhance more effective intervention strategies. Remote-sensing technologies have already been utilized in public health and can provide valuable insights by enabling monitoring of environmental factors, disease vectors, and population movements. This technology helps predict disease outbreaks, assist in planning health interventions, and enable public health professionals to respond to emergencies in a timely manner.

In particular, Sierra Leone has been one of the countries with the most suitable situation for drone technology. In 2019, the government of Sierra Leone, UNICEF, and Njala University jointly launched a drone corridor to improve the efficiency of healthcare delivery. The drone corridor is a designated airspace for testing various drone solutions, including medical deliveries, emergency responses, and geospatial mapping. The Sierra Leonean government, in collaboration with the Civil Aviation Authority and the Directorate of Science Technology and Innovation (DSTI), is working on a regulatory framework to enable the use of drones for maximizing societal impacts. Njala University has committed land to the corridor, allowing researchers and students to gain experience in drone technology.

3. PROJECT GOAL AND SPECIFIC OBJECTIVES

Considering the background indicated above, this project aims to provide a cost-effective vector control strategy against malaria in Sierra Leone by incorporating drone/satellite-based larval habitat monitoring and environmental surveillance systems.

This research seeks the verification of "infection risk index" for each house by examining multiple factors, including the physical/environmental conditions of the house and also the distribution of puddles with potential for suitable environments for mosquito breeding.

In order to address the goals, the specific objectives are stated below;

1. Establishment and verification of "Infection risk "index", by selecting environmental and landscape-related elements, all of which can be accessed by drones and other Artificial Intelligence technologies.

2. Design policy implications: Discuss how drone-based monitoring will enhance cost-effectiveness of several vector control strategies, such as LLIN, IRS and LSM in Sierra Leone. comparing these innovative approaches to conventional designs of vector control.

3. Evaluation of community acceptance: Deepen the understandings on how drone against malaria" can be accepted by the local communities, aiming to create a sense of ownership and cooperation among community members to enhance the effectiveness and sustainability of both interventions

4. Capacity building and training: Build local capacity by providing training and skill development opportunities for technicians and healthcare workers involved in drone-based IRS and LSM.

4. PROJECT METHODOLOGY/ APPROACH

1. Data collection

With the purpose of establishing the **"House Infection Risk Index (HIRI)",** we we will collect significant variables of risk index for each house.

For variables regarded as risk to be infected by mosquito-borne diseases, there are three expectations; number of mosquitoes collected inside, malaria-infected mosquitoes checked or not checked, and whether malaria infection(s) has been confirmed. For example, if house #1 has larger number of mosquitoes

confirmed than in house #2, it will be regarded that house #1 is more prone for someone to be infected in relative to house #2. Moreover, if malaria-infected mosquitoes or patients have been confirmed in house #3 but not in house #4, house #3 will be defined as risky. If it's verified that such factors can be explained with statistically significant results, infection risk index can be predicted with those dominant factors.

Other sets of variables consist of three parts; (1) house-related factors, (2) landscape/environmental factors, and (3) larval habitat-related factors.

(1) house-related factors, e.g., physical parameters about houses, such as roof conditions and conditions of the compound

(2) landscape/environmental factors, e.g., elevations, several parameters related to vegetation and forests.

(3) larval habitat-related factors, e.g., number of larval habitats with type

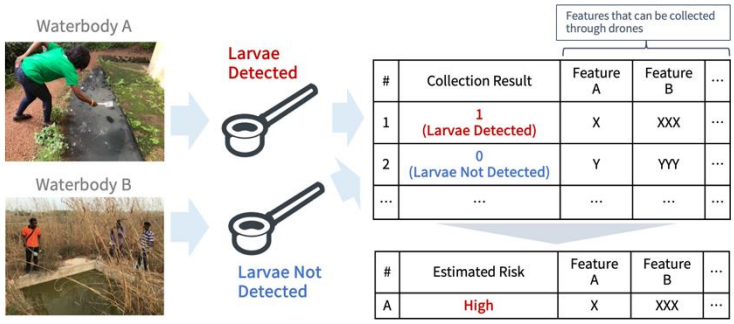
There will be two categories of variables as summarised in the table below.

	Dependent variables			Independent variables								
				House-related factors				Landscape/Environmental factors			Larval habitat-related factors	
House #	# of mosquito collected inside	Whether malaria-infected mosquito checked (Y/N)	Whther malaria patient (s) has been confirmed (Y/N)	Roof condition	Yard condition	Shade condition	...	DSM	NDVI	...	# of waterbodies nearby	...
1												
2												
...												

Table 1 Expected data collection

Dependent variables will be collected by the department of community health at Njala University.

Independent variables will be collected by remote sensing technology centered on drones. For this purpose, we will seek specialized services of SORA Technology in Japan.



SORA Technology has developed a service named "SORA Mosquito Control", through which high-risk mosquito larval habitats are detected by machine learning methods with drone-based sensing data. SORA Technology has provided Artificial Intelligence that can predict the risks of being actual breeding sites out of all the waterbody detected, regardless of size and time, based on the high-resolution geographical data acquired through sensors. Considering that major malaria mosquitoes such as Anopheles Gambiae prefer to breed in smaller transient pools, fixed-wing drones by SORA Technology will be utilised. In our reviews of the academic literature, there no study has been identified that discusses the housing risks considering the

So far, Njala University and SORA Technology have jointly collaborated in several fields[1]. Using a Drone Corridor set inside Njala Campus of Njala University, the demonstrations of SORA Mosquito Control have been conducted several times with some students of Njala University [2]. Moreover, some initial entomological surveys were also conducted jointly, such as collection of actual detailed datasets of actual mosquito breeding sites, and trials on adult mosquito collections in nearby communities

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[1] This collaboration is documented in a Memorandum of Understanding signed with the Directorate of Science, Technology and Innovation

[2] This demonstration is sponsored by the Ministry of Economy, Trade and Industry, Japan. Also, for Sierra Leone, SORA Technology has expanded their services of high-risk larval habitats in nearby western African countries.

Leveraging such technology, SORA Technology will jointly provide the various environmental monitoring data mainly using drones (both multi-copter and fixed-wing, depending on the weather and geographical conditions). After listing up the potential independent variables, all of them will be analyzed either by data processing software (cf. Pix4D), Artificial Intelligence (mainly for larval habitats), and manual checking. In order to assess validation between analyzed data by SORA Technology and actual on-the-ground data, members from Njala University will randomly visit some selected sites in order to evaluate the quality of variables.

2. Target sites

Given Njala University's strategic location and involvement with studies in malaria-prone regions, the identified target sites for malaria observation and research will primarily focus on the fixed points within the Njala University system. These fixed points serve as pivotal locations for consistent and reliable data collection, crucial for the advancement of malaria research. Additionally, the Njala University Hospitals situated on both campuses will be utilized as prominent testing centers. Leveraging the extensive resources and expertise available within the university's healthcare infrastructure, these centers will play a vital role in facilitating comprehensive malaria testing and analysis, ultimately contributing to the broader scope of malaria research initiatives.

3. Data analysis

Housing categorization based on Principal Component Analysis (PCA)

In this study, two statistical analyses have been planned to evaluate the relationship between independent variables and dependent variables, so as to improve the accuracy and simplicity of HIRI.

Firstly, the huge number of independent variables will be analyzed using Principal Component Analysis (PCA). PCA has been widely used to reduce the dimensions of large data sets, by transforming a large set of independent variables into a smaller one that still contains most of the information in the large set. Although reduction of the number of variables in a dataset naturally sacrifices accuracy, it can make the results easier to explore and visualize, as well as improving the speed of machine learning algorithms. By classifying the huge number of houses in the targeted sites into several clusters based on the Principal Components (PCs), the characterization on the houses will be firstly analyzed with easier interpretations. Especially considering the limited number of previous studies which focused on the relationships between some environmental characteristics and infection risks inside the houses, such an improvement on variables will be important. Moreover, such clustering will have some potential to improve future evidence-based strategy design about vector controls beyond the current administration-based decision making.

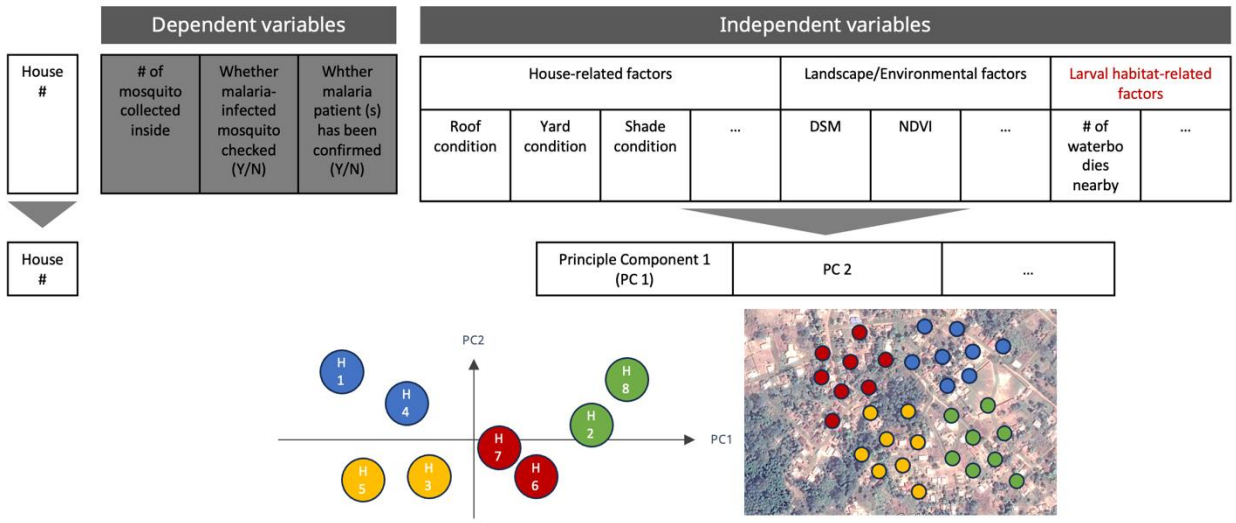


Figure 3 Overview of PCA

HIRI formulation by Partial Least Squares (PLS) Regression

Secondly, based on the PCs as the results of PCA, significantly dominant factors that predict independent variables are discussed. For that analysis, Partial Least Squares (PLS) Regression will be adopted as one of the methods. PLS regression, which is somewhat related to PCA, finds a linear regression model by projecting the predictor and observed variables into a new space. PLS is used to find the underlying relationship between two matrices (X and Y), i.e., the latent variable approach that models the covariance structure of these two spaces. The PLS model tries to find the multidimensional direction in X space that explains the largest multidimensional variance direction in Y space. The PLS regression is particularly suitable when the matrix of predictors has more variables than observations and there is multicollinearity among the X values. In contrast, standard regression fails in these cases (unless regularized). However, it will be heavily dependent on the results of PCA, thus several methodologies related to multiple regression analysis will be considered as well.

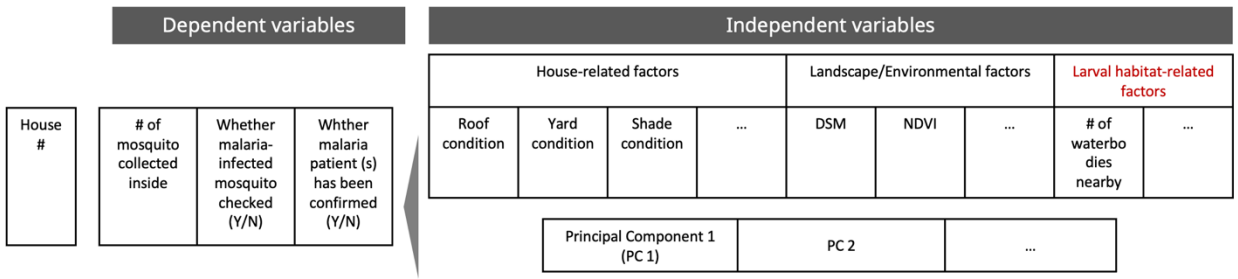


Figure 4 Overview of regression analysis

5. ANTICIPATED OUTPUTS AND OUTCOMES

Expected outcomes can be drawn as the figure below. Based on the outputs of house clustering and regression analysis, one of the main expected outcomes in this research is the identification of high-risk house clusters that can be identified with dominant independent factors. Assuming that climate factors are not variable inside the whole country, HIRI can be widely used to identify such vulnerable communities for indoor mosquito biting. By applying this solution to several communities in Bo district and Communities in Moyamba District, compared with current planning on vector controls, it is expected to propose solutions for improving logistics, such as prioritized distribution of mosquito nets to specific communities. To influence policy and practice, moreover, the research team will actively engage with government officials, policymakers, and healthcare practitioners. They will organize workshops, seminars, and policy briefings to present the research findings and discuss their implications. This engagement will be pivotal in shaping policies and practices related to malaria control.

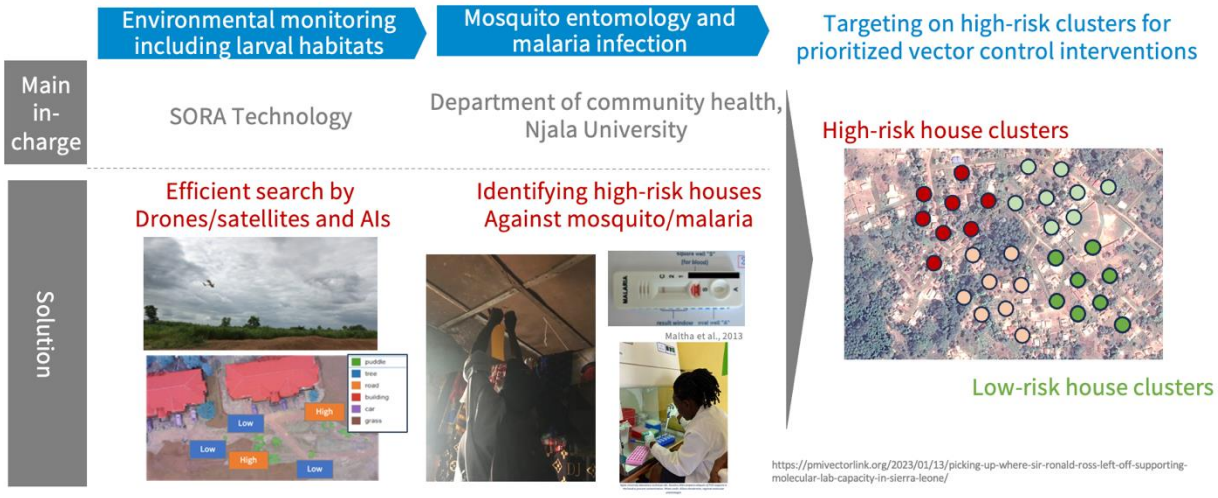


Figure 5 Expected overview of project process and outcomes

6. KNOWLEDGE UTILIZATION AND DISSEMINATION PLAN

Although the understandings on "drone for good" have been widely spread, it is important to pay the largest attention to the community perception and acceptance of our project. In accordance with ethical guidelines by CIOMS (Council for International Organizations of Medical Sciences), therefore, this study is going to have a qualitative-based survey on the communities' perceptions during several drone flight tests. Throughout the study, community-based stakeholder groups were identified and characterized. The key stakeholders are the individuals, groups, and organizations affected by the project. Each stakeholder was categorized according to relative influence (magnitude of impact) and importance (magnitude of influence). The degree of stakeholder engagement can be viewed as a continuum of potential influence over the decision or action being considered, from initial information distribution to stakeholder empowerment.

As parallel with grass-root communications with affected communities, the research findings from the collaborative project between SORA Technology and Njala University will be disseminated with media engagement plans. This will involve collaboration with local and national media outlets, including newspapers, radio, and television. Press releases, interviews, and documentaries will be utilized to raise public awareness about the research and its potential impact on malaria control in Sierra Leone. These efforts will not only inform the general public but also generate interest and support from various stakeholders.

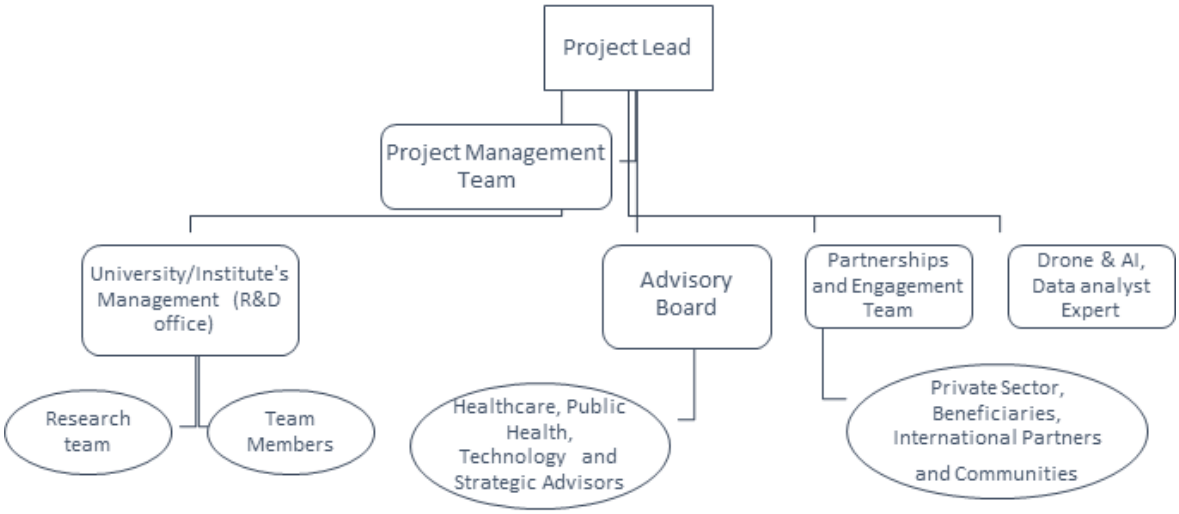
The results will be published as academic articles, and especially open access (OA) is an integral part of the dissemination strategy. Given the importance of sharing knowledge and research findings openly, the project will ensure that research papers and reports are made freely accessible to the public, researchers,

and policymakers. This approach aligns with the principles of transparency and inclusivity, facilitating broader knowledge dissemination and supporting global collaborative efforts to combat malaria.

Overall, this approach maximizes the impact of the research on malaria control in Sierra Leone and beyond.

7. PROJECT GOVERNANCE

The project will have a Project Management Team (PMT) of experts and professionals to oversee all aspects of the project. An Advisory Board of seasoned professionals, researchers, and stakeholders will provide oversight and guidance, ensuring alignment with national and international standards. The research team will consist of multidisciplinary experts with roles and responsibilities in AI, drone technology, malaria control, epidemiology, and data analytics. The project will collaborate with local and international universities and research institutes, leveraging expertise and resources. Beneficiaries, such as local healthcare providers and communities, will be involved through community engagement and capacity-building programs, empowering them to participate in malaria control strategies. The university or institute's management will provide administrative support, secure resources, and facilitate collaboration. This collaborative approach will enhance the project's success by using expertise, resources, and stakeholder engagement effectively



8. SUITABILITY OF THE HOST INSTITUTION

Njala University's cutting-edge infrastructure, including a drone corridor and advanced computing capacity, enables the use of innovative technologies such as drones and AI for malaria control. The institution's proficient team, spanning data science, computer science, public health, and entomology, is well-suited for the research. Moreover, its active participation in public health activities such as the One Health initiative, and with the notable collaboration with SORA Technology to name but a few, underscores its commitment to practical research and its positive impact on local malaria control initiatives.

The existing Memorandum of Understanding with SORA Technology and support from the Directorate of Science, Technology, and Innovation signify its commitment to collaboration and an established network within Sierra Leone's technology and research community.

With access to a drone corridor and established connections with relevant regulatory authorities, Njala University is well-positioned to facilitate the successful implementation of drone technology in the research.

In summary, Njala University's robust technical infrastructure, competent human resources, collaborative efforts, and strategic research alignment make it an ideal institution to lead the research project, utilizing drone and AI technologies for malaria control in Sierra Leone.

9. CAPACITY BUILDING

The project will involve students including post-graduate students in Health, fieldwork and data analysis, providing hands-on experience in cutting-edge technologies like drones and AI to nurture the next generation of researchers in malaria control and technology. Training activities, including workshops and seminars, will benefit not only students but also community members, healthcare workers, and researchers, enhancing the workforce's overall capability.

Project partners, including government agencies and NGOs, will receive training in drone and AI technologies for malaria control, enhancing their contribution and institutional capabilities in these fields.

Through the involvement of post-graduate students, various training activities, and the empowerment of project partners, the project seeks to create a sustainable framework for the adoption of advanced technologies in malaria control while fostering local expertise and strengthening the overall healthcare ecosystem in Sierra Leone.

10. MONITORING AND EVALUATION STRATEGY

To collect data for monitoring and evaluation, the research team working with the University's Research Directorate Team will employ a combination of quantitative and qualitative methods. Quantitative data will be gathered through surveys, drone-based data collection, and AI-driven analytics. Qualitative data, on the other hand, will be obtained through interviews, focus group discussions, and observations. This mixed-method approach will enable the research team to gather comprehensive data that encompasses both the quantitative impact metrics and the qualitative insights necessary to understand the context and community perspectives.

Regular data collection points and intervals will be established to track progress against the project's objectives. This could include monthly, quarterly, or annual data collection, depending on the nature of the indicators being measured. For instance, drone data may be collected more frequently for real-time disease surveillance, while community perceptions and attitudes may be assessed on a quarterly basis.

The research team will also implement a robust data management system to ensure data accuracy, security, and accessibility. This system will include data validation processes, secure storage, and data analysis tools. Additionally, there will be a focus on data transparency, making project findings and data publicly available whenever possible to promote accountability and learning.

Continuous feedback and communication will be key elements of the M&E strategy. The research team will engage with stakeholders, including local communities, healthcare providers, government agencies, and NGOs, to share findings and gather input. This collaborative approach will ensure that the project remains responsive to evolving needs and challenges in the fight against malaria in Sierra Leone.

To ensure the M&E strategy's effectiveness, the University's Quality assurance team will work with the research team and will also conduct periodic reviews and assessments of the strategy itself. This will involve evaluating whether the chosen indicators are still relevant, whether data collection methods are efficient, and whether adjustments to the strategy are needed based on evolving project dynamics or emerging technologies.

This approach will help ensure that the project effectively leverages drone and AI technologies to control malaria in Sierra Leone and contributes valuable insights to the global fight against this deadly disease.

11. GENDER, ETHICS AND SUSTAINABILITY

Gender:

Sora technology and Njala university will conduct a gender analysis to make drone and AI-based malaria control more gender responsive. We will consider how gender affects the access and outcomes and consult with local women's groups and communities. We will also empower women through training them in drone operations and data analytics. Our Initial baseline data collection with the University undergraduate students has been gender inclusive.

Ethics:

Ethical considerations are paramount in our approach to deploying drone and AI technologies for malaria control. We are committed to obtaining informed consent from individuals and communities involved in our project, ensuring they understand the purpose and implications of data collection and monitoring. Strict data privacy and security protocols will be put in place to protect sensitive information and uphold the traditions, rights and dignity of the people of Sierra Leone by ensuring a no fly-zone to cultural sites. Additionally, our collaboration with Njala University will include a dedicated ethics committee responsible for overseeing all research activities to ensure they align with ethical standards and principles. We will also seek guidance and approval from relevant Sierra Leonean regulatory bodies to ensure full compliance with national and international ethical guidelines.

Sustainability:

Sustainability is a core principle of our initiative. We care about sustainability in all aspects. We will use drones responsibily and reduce environmental harm. We will also create local jobs by training, hiring, and making use of locally available materials in Sierra Leone for our drone and AI systems. This will support our project and boost Sierra Leone's economy and human resource. The financial sustainability of SORA Technology's implementation of drones and AI in Sierra Leone is a multifaceted endeavor with significant potential for support from various donors and partners. Among the potential sources of funding, the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Global Fund) and the U.S. President's Malaria Initiative (PMI) stand out as key contributors to malaria control efforts worldwide. Additionally, program support partners such as the World Health Organization (WHO), United Nations Children's Fund (UNICEF), and the Bill & Melinda Gates Foundation (BMGF) have a vested interest in advancing innovative approaches to malaria control, making them potential donors. SORA Technology's strong connections and ongoing discussions with WHO Headquarters (WHO HQ), the Global Fund (GF), and the Bill & Melinda Gates Foundation (BMGF) demonstrate a commitment to collaboration and partnership in advancing malaria control strategies in Sierra Leone. These partnerships can facilitate access to financial resources, technical expertise, and guidance necessary for the successful implementation.

12. PROPOSED PROJECT TIMELINE

Provide a chart of key activities and timelines as below

Project Activities	Year 1				Year 2			
	Q1	Q2	Q3	Q4	QI	Q2	Q3	Q4

Establishment and verification of "Infection risk index" 1. **Data Collection** 2. **Data Analysis**	Planning	**Data Collection & Data Analysis**	**Data Collection & Data Analysis**	**Data Collection & Data Analysis**	**Data Collection & Data Analysis**	M&E		
Design Policy Implications **Policy Discussion** 1. **Evaluating drone-based monitoring for improving Cost effectiveness**	Planning			**Evaluating drone-based monitoring for improving Cost effectiveness**	**Policy Discussion**	M&E		
Evaluation of Community Acceptance 1. **conduct qualitative-based surveys and community meetings** 2. **Stakeholder Analysis**	Planning	**community engagement Stakeholder Analysis**	**qualitative-based surveys**	**qualitative-based surveys**	**qualitative-based surveys**	M&E		
Capacity Building and Training 1. **Training Programs** 2. **Hands-on Training** 3. **Continuous Learning**	Planning	**Training Programs**	**Hands-on Training**	**Hands-on Training**	**Continuous Learning**	M&E		

13. LITERATURE CITED

Include key literature/references that have been cited in the proposal

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