

# Using Polio GIS Maps to Increase Coverage during Mass Immunization Campaigns in Northern Nigeria

Mahmud Zubairu Mahmud (✉ [mahmudisnow@gmail.com](mailto:mahmudisnow@gmail.com))

World Health Organization <https://orcid.org/0000-0002-0563-1587>

Vincent Seaman

Bill & Melinda Gates Foundation

Mustafa Zubairu Mahmud

National Primary Healthcare Development Agency

Kebba Masireh Touray

World Health Organisation: Organisation mondiale de la Sante

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## Research article

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# Abstract

**Background.** Historically, vaccinators struggled to reach all settlements during mass polio campaigns in northern Nigeria because of poor micro plans. This made it difficult to attain the high immunization coverage necessary to interrupt transmission of polio virus in the region. The objective of this study was to devise a means to reach all settlements - Built-Up Areas (BUAs), Small Settlements (SSAs), and Hamlet Areas (HAs) - visible on satellite imagery and thereby significantly increase the overall coverage during mass polio immunization campaigns.

**Methods.** The procedure by which geographic information system **GIS** drawn maps can be used to improve immunization coverage is presented, along with the extent to which the maps increase immunization coverage when incorporated into team micro plans in northern Nigeria. The method involves training on map comprehension to relevant health workers and vaccination campaign or Immunization Plus Days (IPDs) personnel - who are then able to use the GIS Ward maps to create clusters of settlements, roughly equal in population, commensurate with the total number of vaccination teams allocated to the ward. The maps were then used to guide IPDs personnel in providing polio immunization services to all households in the ward during the January 2019 mass polio immunization campaign. The study area was a distinct and homogeneous geographical area called Horserizum Ward in Hong Local Government Area (LGA) of Adamawa state, Nigeria. The study population was comprised of all resident households or members of the communities (totaling 19,698 persons by the recent local census) in the Ward.

**Results.** At the conclusion of the January campaign, the number of settlements in the Ward unreached by health workers (as shown by the GIS dashboard, [www.vts.eocng.org](http://www.vts.eocng.org)) was compared to previous polio immunization campaigns when no GIS maps were used to guide vaccination activities. Results revealed an immunization coverage for hamlet areas HAs (which is the main settlement type where coverage needed to be improved) of 82% (for January 2019 campaign) versus 43% during the previous campaign held in December 2018.

**Conclusions.** The results were statistically significant ( $P < 0.0000001$ ,  $t = 5.175$ .) and we conclude that, using GIS maps to guide vaccination activities (GIS micro planning) has a very significant positive impact on immunization coverage, especially in rural, hard-to-reach, or scattered settlements.

## Introduction

The history of mass polio campaigns (Immunization Plus Days or **IPDs**) dates back to 1988 when the world health assembly declared a plan for polio eradication (<https://www.who.int/news-room/detail/25-05-2017>). Before then, the disease had ravaged the globe with a burden of over 350,000 paralyzed polio victims every year (<https://www.who.int/news-room/fact-sheets/detail/poliomyelitis>). The World Health Organization (WHO) provided 2 main strategies as a method of freeing the world completely of polio: namely immunization (of which there are several types) and acute flaccid paralysis **AFP** surveillance

(<http://www.emro.who.int/polio/strategy/>). The use of these strategies, has led to a remarkable reduction in the number of polio cases worldwide, with the disease virtually nonexistent today in most countries. Indeed, according to the WHO the only remaining polio endemic countries on the globe (as of today 2019) are Pakistan, Afghanistan and Nigeria ([polioeradication.org/polio-today/polio-now/this-week/](http://polioeradication.org/polio-today/polio-now/this-week/)).

The Nigeria polio problem can be broken down into three main areas: noncompliance to immunization, vaccination team safety, and vaccination team attitude. Noncompliance to immunization refers to households that are averse to immunization, and these are more common in the northern region (Abdulaziz Mohammed et al., 2014). In this part of the country, many do not believe in immunization because of religious beliefs, superstition, lack of education or awareness, or distrust of “free” government programs. Consequently, even when presented with vaccines by health workers going house to house during mass polio campaigns, they do not allow their children to be vaccinated. Hence their young children are at a very high risk of polio infection, and as a result the region has found it difficult to interrupt transmission of polio. Vaccination team safety is threatened by infighting and communal clashes (either herdsmen versus farmers or clashes of ethnic origin) along with armed banditry and terrorism. These incidents have rendered many communities across large swaths of the north inaccessible to vaccination teams. Experts argue that until all children trapped in inaccessible communities are vaccinated, transmission of polio will continue to occur in Nigeria (36<sup>th</sup> meeting of the expert review committee on Polio eradication and Routine Immunization, Abuja, Nigeria. October 2018). Lastly, vaccination team attitude refers to the negative behavior and performance of health workers who support polio vaccination. Many public health experts believe that this may have the greatest impact on the nation’s polio program as it cuts across all regions of the country. Vaccination team attitude can have negative effects on the program in several ways, including: vaccinators deliberately refusing to visit settlements of assignment during campaigns; vaccinators simply dumping polio vaccine while falsely adding the number of names to the tally sheet corresponding to the number of doses poured away; and vaccinators colluding with heads of noncompliant households to mark children as vaccinated (a finger mark with indelible marker) when they do not, in fact, receive the vaccine.

Despite these problems, the country has made great progress in stopping polio ([polioeradication.org/where-we-work/nigeria/](http://polioeradication.org/where-we-work/nigeria/)). Much of the success achieved in polio eradication initiative (**PEI**) in the country today is attributable to the intervention of government and many (nongovernmental organizations) **NGOs** directly tackling these problems of noncompliance, insecurity and team attitude at all levels. One particularly impactful innovation that some feel was the game changer in the history of polio eradication in Nigeria (<https://www.slideshare.net/.../how-the-polio-eradication-effort-in-nigeria-led-to-a-quest-for-global-geospatial-reference-data>), was conceived and implemented by the Global Polio Eradication Partners GPEI partners (mainly WHO, National Primary Health Care Development Agency, Abuja Nigeria NPHCDA, and the Bill & Melinda Gates foundation) in 2011. This innovation, called the Vaccination Tracking System (VTS), employs geographic information system **GIS** technology to track vaccinators and hence provides evidence that settlements are, in fact visited, as well as giving immunization coverage at the end of every mass campaign on a monitoring

screen (called the **GIS** dashboard - [vts.eocng.org/Home/About](http://vts.eocng.org/Home/About)). The VTS involves giving well-charged android phones (that collect GPS tracks every 2 minutes) to vaccinators during working hours of any mass polio campaign. At the end of each day's activity, the phone data are uploaded to a central server, and GIS software (ArcMap, ESRI, USA) is used to reveal the tracks (GPS locations) of the vaccinators for the entire day. The data is also shown on the VTS website (<http://vts.eocng.org/>) and then exported to the GIS Dashboard which is used by the polio Emergency Operations Centers to view VTS data. The outputs include accurately drawn **GIS** maps of the entire country, with all human habitations - namely towns, villages and hamlets - named and identified with geocoordinates (Inuwa Barau, Mahmud Zubairu, et al., 2014). Any human habitations without GPS tracks are classified as "missed" as there is no evidence they were visited/reached by vaccinators, and those with only very few tracks are "poorly reached/covered." Built-up areas (urban) are divided in to a 50 meter grid, and coverage is based on the number of grid squares intersected by a track. Overall coverage is then calculated and displayed on the **GIS** dashboard during and after polio campaigns ([www.vts.eocng.org](http://www.vts.eocng.org)). Since the introduction of VTS, the progress of the Nigeria polio program has improved significantly and many public health experts believe that they are finally close to eradication.

Prior to every house-to-house mass polio immunization campaign in Nigeria a micro plan containing details of all settlements (towns, villages or hamlets) within a given region of assignment is prepared by the Ward micro plan revision team - a gathering of the traditional leaders, vaccinators and health workers resident in the ward. In the context of IPDs in Nigeria, a micro plan is a simple document carried by vaccinators during mass immunization campaigns that contains the list of all areas (settlements) they intend to visit within the days of the campaign; the estimated number of children between the ages of zero and five years living in those settlements; the estimated doses of vaccine required to vaccinate the children and the most appropriate means of transport to get to the settlements. With a comprehensive line list of settlements within a ward (in this case, Horserizum Ward of Hong LGA of Adamawa, Nigeria), it vaccinators should be able to cover all assigned areas during immunization campaigns, except for two reasons: namely poor team attitude and/or a faulty micro plan. Team attitude can be addressed with intensive supervision coupled with vaccination tracking of health workers. A faulty micro plan, however, implies not all settlements in the ward were actually line-listed in the first place by the ward micro planning revision team. In order improve the quality of micro plans the GPEI partners began the collection of georeferenced settlement data for all wards in Nigeria. The maps were constructed by obtaining all X and Y coordinates of line listed settlements on the existing ward micro plan and viewing them on satellite imagery. Any settlements seen on the imagery which were not identified by the initial data collection were flagged and assigned machine or computer generated names - 'small settlement areas' (SSAs) for small villages or 'hamlet areas' (HAs) for small rural clusters of dispersed buildings. Large urban areas called built up areas (BUAs) were rarely missing from the micro plans.

The GIS maps revealed faulty micro plans in nearly every Ward across the country. The maps in most cases contain about 5% machine-named SSAs and HAs that are missing from Ward micro plans. It is not surprising that despite many rounds of mass polio campaigns in Nigeria, many SSAs and HAs are not reached by vaccinators - not because they deliberately refuse to do so (team attitude), but due to a faulty

micro plan. Experts agree that once vaccinators are tracked (given phone trackers during mass polio campaigns) and micro plans thoroughly revised such that all human habitation in a ward are assigned locally recognizable names, the issue of low immunization coverage due to missed settlements would be resolved. GIS micro planning thus refers to the revision of ward micro plans for mass polio campaigns using GIS drawn maps, and is the basis for this study.

## **JUSTIFICATION**

Analysis of GIS dashboard information over time revealed very poor coverage of some settlement areas (particularly hamlet areas) during mass immunization campaigns in Adamawa State. The dashboard uses the presence of GPS tracks in settlements to calculate immunization coverage in a scientific manner & is freely available on the web at [www.vts.eocng.org](http://www.vts.eocng.org). Per the dashboard analytics, any settlements without GPS tracks after the conclusion of mass Polio campaigns are classified as “missed” and those with only very few tracks are “poorly covered”. In Horserizum Ward of Hong LGA for instance, after the conclusion of the December 2018 IPDs, only 80% of villages and 43% of hamlets were reached by vaccinators (the rest were either missed or poorly covered).

Indeed, a total of about 6 hamlet areas (mostly with machine generated names) in the Ward were not covered at all. Machine generated hamlet areas are tiny hamlets (maybe one-man camps, migratory groups, or scattered clusters of 10 dwellings or less) not reflected in the updated ward micro plan list but sighted through satellite imagery and presumed to contain eligible children for vaccination. Despite repeated update of micro plans every round, these hamlet areas have not been identified with any local names hence a difficulty in assigning them to teams for vaccinations. The resident children in these areas that are consistently missed during polio campaigns constitute the very high-risk group and are a major hurdle to achieving polio eradication in the country. Thus, any innovation to locate and vaccinate these at-risk kids is what the country requires now!

## **OBJECTIVE**

The objective of the activity was twofold:

1. Reach all settlements (BUAs, SSAs, HAs) visible on satellite imagery and
2. Significantly increase the overall immunization coverage through better coverage of hamlet areas

## **HYPOTHESIS TESTING**

The following hypothesis was tested in the study, all at 1% level of significance;

*Null hypothesis:* The number of machine generated hamlet areas reached with Polio vaccinations (& hence immunization coverage) is not contingent on the type of IPDs micro-planning.

*Alternate Hypothesis:* The number of machine generated hamlet areas reached with Polio vaccinations (& hence immunization coverage) is contingent on the type of IPDs micro-planning.

## SCALE OF IMPLEMENTATION

The activity was piloted in a rural ward of Hong LGA called Horsherizum with a total of 11 vaccination team members participating.

## Methodology

The production of GIS based micro plan for use in the implementation of January 2019 IPDs in Horsherizum ward – the study area and indeed for any ward in northern Nigeria -involves the following steps carried out in a sequential manner:

1. Convene the ward micro plan revision team, comprised of traditional leaders, religious leaders, ward focal persons, vaccination team members and other GPEI partners present in the ward.
2. Display on the wall a large (preferable A2 size) GIS map of the ward.
3. Using 'legend, scale and orientation', a facilitator (the WHO cluster consultant in this case) explains the use of the map, symbology, etc., to the micro plan revision team. The settlements shown on the GIS map are reviewed one-by-one by the committee, ensuring all agree on the names and locations, as well as their approximate distances from each other.
4. Once all named settlements on the GIS map are confirmed, the committee attempts to place names on the remaining machine named SSAs and HAs on the map.
5. The Ward focal person (WFP) then divides the GIS drawn map with a heavy marker into clusters (seven clusters in the study Ward) commensurate with the number of house-to-house teams allocated to the ward for the IPDs implementation. These are called team work areas.
6. The demarcated team work areas are further reviewed to ensure they are approximately the same total population, and include similar travel distance/time between settlements. The approximate population of each settlement is obtained from the committee members and compared to the GIS population estimates created as part of the GPEI mapping exercise.
7. Two days before implementation, each team (composed of a supervisor, a vaccinator, and a community leader) conducts a 'logistics' tour of the allocated cluster of settlements to familiarize themselves with the area and to determine where to begin work on day1 of implementation.
8. After the logistics tour, team supervisors then divide the each cluster of settlements on the ward GIS drawn map into 4 areas with roughly equal population and travel distance requirements, to identify settlements to be visited by the vaccination team members on Days 1-4 of the IPDs, which completes the GIS micro plan. Annex A is a copy of the Horsherizum GIS micro plan.
9. Each day of implementation, the team supervisor receives a well-charged phone tracker and returns it at the close of business to be uploaded to the VTS server by a GIS technician (from a a global polio eradication partner in Nigeria).
10. The final results (after 4 days of activity) are made available on the GIS dashboard at [vts.eocng.org](http://vts.eocng.org), and any settlements still without tracks are considered missed areas (i.e. not visited by vaccination

teams).

## DATA COLLECTION INSTRUMENTS

The following tools were used to collect and display all relevant information:

- Android phones (trackers)
- GIS dashboard
- Latest GIS ward/Team area maps
- House to house vaccinations tally sheets.

## Results

The results below were obtained from the study. They were extracted from both the GIS dashboard and vaccination team tally sheets as at January 31<sup>st</sup>,2019 immediately after conclusion of the January IPDs, and were evaluated in a 'before and after' manner. 'Before' refers to December 2018 IPDs when GIS micro planning was not done and 'after' means January 2019 IPDs when GIS micro planning was done in Horsherizum ward. The procedure for pulling out results from the GIS dashboard is briefly as follows:

- i. Search web or go to [www.vts.eocng.org](http://www.vts.eocng.org)
- ii. Tab on the menu 'geographic coverage' and then pull down month and year of immunization campaign done at the extreme right hand corner.
- iii. Click on state to pull up state immunization coverage
- iv. Similarly, pull up LGA immunization coverage by clicking on details and also ward immunization coverage in that fashion
- v. Finally, click details under each ward to obtain immunization coverage of all three settlement types namely built up areas **BUAs**; small settlement areas **SSAs** and hamlet areas **HAs**. Built up areas refer to communities that have over a hundred households with an urban grid layout and composed of mainly cement block buildings. In the Nigerian context, these are usually towns or big villages. Small settlement areas are communities with between 20 - 100 households. They are mostly villages. Hamlet areas as the name suggests are groups of human habitations with less than 20 households (hamlets) that are within 200 meters of one another. In Nigeria, these are either nomadic camps or dispersed rural communities.

**Results 1: Performance of android tracking phones** – measured as team reporting/teams deployed obtained from the GIS dashboard at [www.eocng.org](http://www.eocng.org). This number represents the *completeness* of the tracking data. A value of 100 was obtained in both the 2018 and 2019 rounds of IPDs

**Results 2: Cumulative immunization coverage of BUAs, SSAs & HAs** – obtained from the GIS dashboard at [www.eocng.org](http://www.eocng.org).

Graph 1. Cumulative immunization coverage of BUAs, SSAs and HAs in Horsherizum ‘before’ and ‘after’ (see Supplementary Files).

**Results 3: Oral Polio Vaccine, OPV doses used and children immunized** – obtained from vaccination team tally sheets

Graph 2. Oral Polio Vaccine (OPV) doses used and children immunized; Horsherizum ward (see Supplementary Files).

**Results 4: Settlements reached and vaccination coverage, urban areas**

**(BUAs)** – obtained from the GIS dashboard at [www.eocng.org](http://www.eocng.org).

Table 1. Settlements reached and vaccination coverage, urban areas or BUAs only.

Settlement Name	Settlement Type	Cumulative % Visited Dec 2018	Cumulative % Visited Jan 2019
Biri Mullah	Urban Area	70	88.46
Jauro Muazu	Urban Area	70	70
Likuku	Urban Area	70	80.6
Makera Jauro Hussaini	Urban Area	76	82
Mustapha Yakubu Mukhtar	Urban Area	70	71.74

**Results 5: Settlements reached and vaccination coverage, small settlement areas (SSAs)** – obtained from the GIS dashboard at [www.eocng.org](http://www.eocng.org).

Table 2. Settlements reached and vaccination coverage, small settlement areas or SSAs only.

Settlement Name	Settlement Type	Cumulative % Visited Dec 2018	Cumulative % Visited Jan 2019
Barkari I	Small Settlement	100	100
Barkari II	Small Settlement	100	100
Dadawaloji	Small Settlement	100	100
Gangni B	Small Settlement	100	100
Garari	Small Settlement	100	100
Jaba Banshika	Small Settlement	100	100
Jabba Dziga Yerima	Small Settlement	100	100
Jabba Hoshiheri	Small Settlement	100	100
Kwanchafarm	Small Settlement	0	100
Luga	Small Settlement	100	100
Madagali	Small Settlement	100	100
Mairanawo	Small Settlement	0	100
Makera Jauro Ibrahim	Small Settlement	0	100
Matafash	Small Settlement	100	100
Mombol Krabiri	Small Settlement	100	100
Mombol Ndlabiri	Small Settlement	100	100
Tudu	Small Settlement	100	100
Unguan Jauro Martine	Small Settlement	100	100
Wafaati	Small	0	100

	Settlement		
Wuro Garba	Small Settlement	100	100

**Results 6: Settlements reached and vaccination coverage, hamlet areas (HAs)** – obtained from the GIS dashboard at [www.eocng.org](http://www.eocng.org).

Table 3. Settlements reached and vaccination coverage, hamlet areas or HAs only

Settlement Name	Settlement Type	Cumulative % Visited Dec 2018	Cumulative % Visited Jan 2019
Arndo Fulani	Hamlet Area	80	80
Arndu	Hamlet Area	100	100
Chakamaje	Hamlet Area	100	100
Chirali	Hamlet Area	80	100
Dulhuba	Hamlet Area	100	100
HA_1	Hamlet Area	50	100
HA_10	Hamlet Area	100	100
HA_12	Hamlet Area	50	50
HA_14	Hamlet Area	100	100
HA_18	Hamlet Area	50	100
HA_19	Hamlet Area	50	50
HA_2	Hamlet Area	100	100
HA_21	Hamlet Area	100	100
HA_23	Hamlet Area	50	100
HA_24	Hamlet Area	50	50
HA_25	Hamlet Area	100	100
HA_3	Hamlet Area	100	100
HA_4	Hamlet Area	100	100
HA_5	Hamlet Area	0	100
HA_6	Hamlet Area	0	0
HA_7	Hamlet Area	50	100
HA_8	Hamlet Area	50	100
HA_9	Hamlet Area	100	100
Kesure	Hamlet Area	50	100
Kwaghkba	Hamlet Area	0	100
Kwatsin	Hamlet Area	100	100
Lafakin	Hamlet Area	0	100
Luga Fulani	Hamlet Area	40	80
Naderi	Hamlet Area	0	66.67
Nassarawo	Hamlet Area	50	66.67
Njaringa	Hamlet Area	100	100
Public Well	Hamlet Area	50	100
Sikali	Hamlet Area	50	100
Tsohon Gari	Hamlet Area	0	100
Ungwa Murulei	Hamlet Area	100	100

Vindi Abache	Hamlet Area	0	88.89
Wuro Baba Iya	Hamlet Area	100	100
Wuro Babeyo	Hamlet Area	66.67	100
Wuro Bali	Hamlet Area	0	60
Wuro Biriji	Hamlet Area	100	100
Wuro Gau	Hamlet Area	100	100
Wuro Jabbe	Hamlet Area	50	100
Wuro Mbaya	Hamlet Area	100	100
Zhir	Hamlet Area	100	100

**Results 7: Results obtained when the student's T-test statistics is applied to the vaccination coverage of hamlet areas HAs 'before' (December 2018) and 'after' (January 2019)**

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	90.7325	64.01523
Variance	429.4465448	1419.421
Observations	44	44
Pearson Correlation	0.433007868	
Hypothesized Mean Difference	0	
df	43	
t Stat	5.175110799	
P(T<=t) one-tail	2.84685E-06	
t Critical one-tail	2.416250129	
P(T<=t) two-tail	5.6937E-06	
t Critical two-tail	2.695102079	

## Discussion

The value of 100 reported in **results 1** as the percentage of phones reporting indicates that all of the tracking phones used during both campaigns (year 2018 and 2019) were received and at the end of each day and data was uploaded without incident. There were no reports of phones switching off on their own in the field during usage, dead batteries, or other malfunctions. Therefore, any settlement in the study area without tracks is not because any phones malfunctioned but because no vaccinator visited the area.

Results 2 show that the immunization coverage for all types of settlements was increased after GIS micro planning was implemented. A critical look at the figures, however, suggests that the effect is more

pronounced on the coverage of HAs. Before GIS micro planning, immunization coverage of HAs in Horsherizum was 43%, compared to 82% after GIS micro planning. On the other hand, percentage immunization coverage of BUAs before and after was 71 and 74% respectively – which is not a significant difference given the small size of the study.. Unlike HAs, BUAs and SSAs are conspicuous areas of human habitations, and lie alongside or at the nexus of major roads. They are often very well known to every member of the vaccinating team and usually areas first listed on conventional walk through micro plans as areas to be covered by any team. It is therefore not surprising that immunization coverage of BUAs and SSAs is least affected by GIS micro planning. Once a settlement is correctly listed and assigned a locally recognizable name, any vaccinator should reach it if provided the right motivation. Thus, a simple conclusion that can be drawn from results 2 is that, the micro plans used by teams in Horsherizum ward during January 2019 IPDs allowed them to reach more hamlet areas than that employed in December 2018 (conventional walk through micro plans). But is this ‘statistically’ significant?

**Results 3** indicates that more children and accordingly more doses of vaccines were used in Horsherizum in January 2019 when GIS micro planning was done compared to December 2018 when it was not. This is in agreement with immunization coverage seen in Results 2 above as the doses of vaccine used reflect the number of children immunized. It is the result of good data quality and the fidelity of GIS micro planning in increasing immunization coverage during mass immunization campaigns. It is pertinent to note however that, the difference in OPV doses used and children immunized (graph 2) is not as apparent as immunization coverage depicted in graph 1 because only very few persons live in hamlet areas. Hamlet areas in northern Nigeria are mostly a one man’s camp with very few kids yet very ‘valuable’ in terms of Polio eradication as they are at most times not reached during mass immunization campaigns. So, even when all of them are reached by vaccinators using GIS micro planning technic during campaigns, it will not have a profound effect on doses of vaccine used because the number of children so reached is very small compared to the total population of children residing in BUAs and SSAs who are consistently reached during Polio campaigns.

**Results 4** suggest that there is no need for GIS micro planning in order for vaccinators to cover BUAs properly. As a matter of fact, there isn’t a significant difference in immunization coverage of BUAs when GIS micro plans were used compared to when they were not. As already mentioned in paragraph two above, this is not surprising and only implies that only strong supervision and ‘team motivation’ are required. Indeed, statistically, at 1% level of significance, there’s no statistically significant difference in the two immunization coverage results for BUAS (December 2018 versus January 2019) and we conclude that use of GIS drawn maps for micro planning appears to have no effect on coverage of BUAs.

A cursory look at **results 5** reveals that a total of four small settlements - namely KWACHAFAM, MAIRANAWO, MAKERA JAURO IBRAHIM & WAFATI that were not reached at all by vaccinators in 2018 were visited in January 2019 when GIS micro plans were employed. Although it is important for polio eradication that these five settlements are covered (likely for the first time), analysis of the entire immunization coverage data for small settlement areas (SSA) statistically using the students T-test and

at 1% level of significance shows no significant difference between 2018 and 2019 immunization coverage data for SSAs. Thus, while using GIS micro plans did not statistically improve immunization coverage for SSAs, the fact that 5 settlements were covered for the first time is an important event. Indeed, as earlier postulated, once a settlement is correctly line-listed and assigned a locally recognizable name (as with all SSAs on GIS maps or walk through micro plans), any vaccinator should reach it if he or she is provided the right motivation.

Regarding coverage of HAs (**Results 6**), GIS micro planning has a profound effect. Aside from facilitating the vaccination team's visit to seven HAs that were completely missed in 2018, , many HAs that were previously poorly covered in 2018 also had their coverage tremendously increased. Furthermore, statistical analysis of immunization coverage results depicted in **results 6** (shown in the table below using the students T – test) revealed a significant difference between immunization coverage of HAs in 2018 versus 2019. This strongly suggests the rejection of the 'Null hypotheses. Thus, it appears the number of machine generated **HAs** reached with polio vaccinations (& hence immunization coverage) is contingent on the type of IPDs micro-planning. Indeed, by the results statistics, the probability that all HAs were reached by chance in the Horsherizum ward during January round of IPDs when GIS micro planning was used for implementation is about 1 in a 10,000.

## Conclusions/recommendations

We conclude that when GIS micro planning was undertaken in January 2019, the quality of immunization as measured by immunization coverage - particularly of hamlet areas - was much better than in December 2018 when there was no GIS micro planning. Statistical analysis revealed that there is indeed significant difference between immunization coverage in Horsherizum ward' before and after the study. As majority of Nigeria's underserved population in terms of the provision of health services, including immunization, live in hamlet areas, coupled with the fact that these settlements are most often missed based on vaccination team tracking data, any innovation to enhance the ability of vaccinators to find and reach them is important. It is therefore strongly recommended that GIS micro planning be adopted by WHO Adamawa to help vaccinators reach the high number of hamlet areas chronically missed during the many rounds of mass Polio campaign in northern Nigeria.

## Abbreviations

GIS – Geographic Information System

BUAs – Built Up Areas (means big towns or communities that are part of a big town)

SSAs – Small Settlement Areas (refers to small villages)

HAs – Hamlet areas (refers to scattered and very small camps)

IPDs – Immunization Plus Days'

WHO – World Health Organization

AFP – Acute Flaccid Paralysis

PEI – Polio Eradication Initiative

NGOs – Non Governmental Organization

GPEI – Global Polio Eradication Initiative

NPHCDA – National Primary Health Care Development Agency

VTs – Vaccination Tracking System

GPS – Global Positioning System

WFP – Ward Focal Person

OPV – Oral Polio Vaccine

## Declarations

**Ethics approval and consent to participate:** No consent is required to initiate the study

**Consent for publication:** No consent is required from any quarters

**Availability of data and material:** All relevant and necessary data implied in this study are available at the GIS dashboard. This can be accessed at [www.vts.eocng.org](http://www.vts.eocng.org)

**Competing interests:** There are no competing interests what so ever!

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## Figures

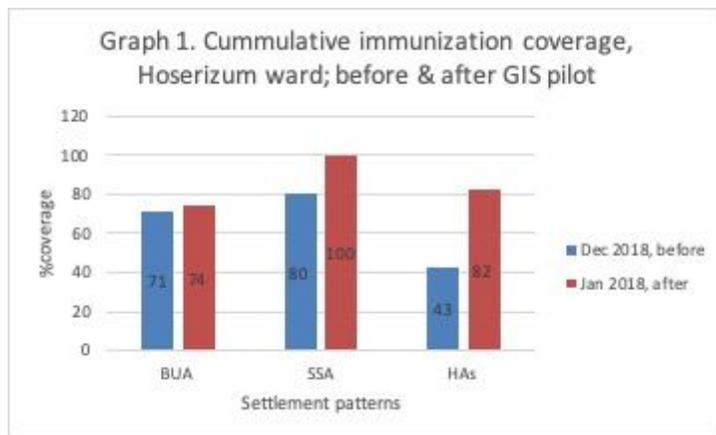
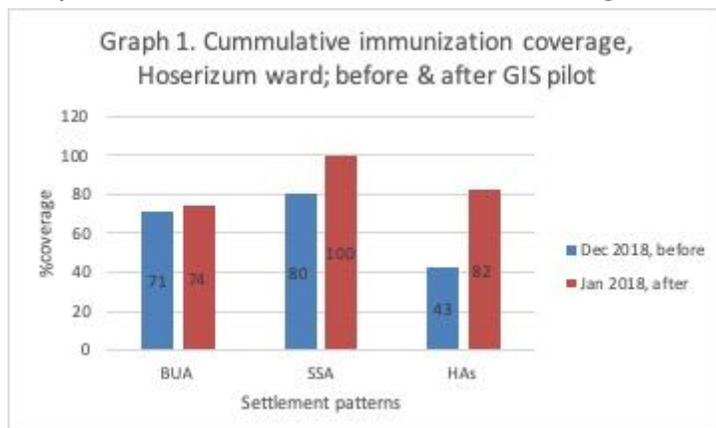


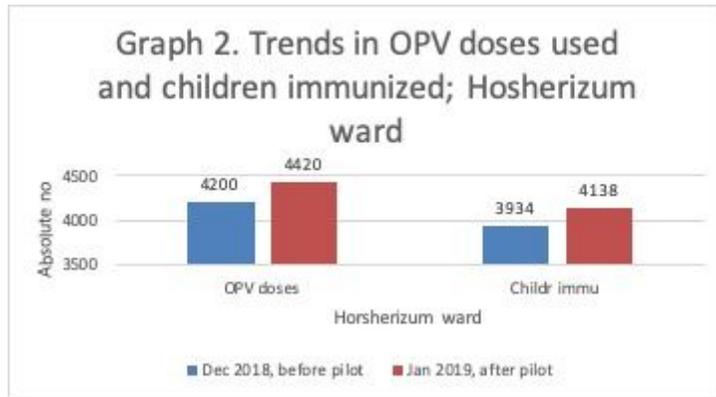
Figure 1

Graph 1. Cumulative immunization coverage of BUAs, SSAs and HAs in Horsherizum 'before' and 'after'



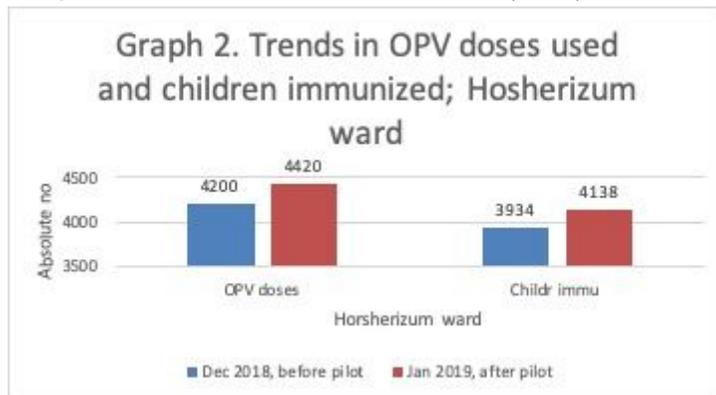
## Figure 1

Graph 1. Cumulative immunization coverage of BUAs, SSAs and HAs in Horsherizum 'before' and 'after'



## Figure 2

Graph 2. Trends Oral Polio Vaccine (OPV) doses used and children immunized; Horsherizum ward



## Figure 2

Graph 2. Trends Oral Polio Vaccine (OPV) doses used and children immunized; Horsherizum ward

## Supplementary Files

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- [Graphs1and2.pdf](#)
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