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Assessing the use of geospatial data for immunization program implementation and associated effects on coverage and equity in the Democratic Republic of Congo

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Abstract

Background The National Expanded Program on Immunization in the Democratic Republic of the Congo implemented a program in 9 Provinces to generate georeferenced immunization microplans to strengthen the planning and implementation of vaccination services. The intervention aimed to improve identification and immunization of zero-dose children and overall immunization coverage.

Methods This study applies a mixed-methods design including survey tools, in-depth interviews and direct observation to document the uptake, use, and acceptance of the immunization microplans developed with geospatial data in two intervention provinces and one control province from February to June 2023. A total of 113 health facilities in 98 Health Areas in 15 Health Zones in the three provinces were included in the study sample. Select providers received training on gender-intentional approaches for the collection and use of geospatial data which was evaluated through a targeted qualitative study. A secondary analysis of immunization coverage survey data (2020–2022) was conducted to assess the associated effects on immunization coverage, especially changes in rates of zero dose children, defined as those aged 12–23 months who have not received a single dose of Pentavalent vaccine.

Results This research study shows that georeferenced microplans are well received, utilized, and led to changes in routine immunization service planning and delivery. In addition, the gender intervention is perceived to have led to changes in the approaches taken to overcome sociocultural gender norms and engage communities to reach as many children as possible, leveraging the ability of women to engage more effectively to support vaccination services. The quantitative analyses showed that georeferenced microplans may have contributed to a dramatic and sustained trend of high immunization coverage in the intervention site of Haut-Lomami, which saw dramatic improvement in coverage for 3 antigens and little change in Pentavalent drop-out rate over three years of implementation.

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Conclusion The overall study identified positive contributions of the georeferenced data in the planning and delivery of routine immunization services. It is recommended to conduct further analyses in Kasai in 2024 and 2025 to evaluate the longer-term effects of the gender intervention on immunization coverage and equity outcomes.

Trial registration The study was registered and given BMC Central International Standard. Randomised Controlled Trial Number ISRCTN65876428 on March 11, 2021.

Keywords Geospatial data, Mapping for health, Immunization coverage, Vaccine coverage survey, Immunization equity, Democratic republic of the congo, Expanded program for immunization, Routine immunization, Zero dose, Microplanning

Background

The World Health Organization (WHO) Global Vaccine Action Plan (2011–2020) was developed to help all individuals and communities enjoy lives free from vaccine-preventable diseases, demonstrating that the benefits of immunization are equitably extended to all people, wherever they are located [1]. Gavi, the Vaccine Alliance's 5.0 Strategy 2021–2025 and the Global Immunization Agenda 2030 [2, 3] promote the use of geospatial data and technology applications for immunization programs to reach all children, especially unvaccinated children referred to as "zero-dose".

In the Democratic Republic of the Congo (DRC), the Mashako Plan is a unique, high-level national health strategy that aims to drastically increase complete childhood immunization coverage at a national level [4]. The integration of geospatial tools, technologies and data for planning and delivery of immunization services supports the Mashako Plan through a participatory process to create geospatially accurate maps of settlements, define health area boundaries and generate improved population estimates. The integration of these geospatial tools and technologies into immunization programs has demonstrated potential to enhance immunization coverage and equity [5] and address persistent challenges of data quality, inflated reports of coverage rates and inaccurate denominators [6, 7]. The use of geospatial data, geospatial tools and technologies for immunization programming in the DRC was intended to address some of these challenges and to support the immunization program to accurately monitor immunization coverage and plan upcoming vaccination activities.

Description of the intervention

The Mapping for Health (M4H) project aimed to strengthen the equity and effectiveness of vaccination interventions in the DRC, increase national geospatial capacities and promote gender-intentional programming through the provision of geo-enabled microplans within the National Expanded Program on Immunization (NEPI). The project has been implemented by the Ministry of Health with support from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) Consortium since 2019.

To improve the effectiveness of immunization microplans, the GRID3 Consortium supported the National Immunization Program activities to promote gender-intentional planning and to generate geospatial data and population modeling to determine the target population (denominator) and produce core geospatial data layers: settlements, health boundaries, and health facilities. These data were then used to optimize vaccination strategies in Health Zones in the form of geo-enabled microplans.

While gender equity in the delivery of vaccines is of critical importance, gender also plays a role in relationships between health workers and supervisors, digital literacy, division of labor, data use, decision-making and leadership within the health system [8]. The cultural contexts and gendered barriers among health providers and the communities they serve can impact the adoption, access and use of digital technologies that are intended to improve immunization outcomes. For this reason, the M4H intervention included a gender audit, a series of gender trainings to strengthen stakeholder capacity to understand and apply gender-intentional principles in program design and implementation, multi-sectoral stakeholder engagements and a gender-based analysis tool. In collaboration with the Ministry of Gender and Social Affairs these gender interventions promoted strategies to engage more women in the process of generating and utilizing geospatial data and to apply gender-responsive strategies to immunization program planning and service delivery using the geo-enabled microplans. These activities were carried out in one study Province (Kasai) in targeted Health Zones and Health Areas where the gender intervention was evaluated separately using a rapid ethnographic sub-study.

To evaluate the adoption and use of geo-enabled microplans and the complementary gender intervention in a sub-set of sites, Gavi, the Vaccine Alliance engaged health.enabled through the "Effective Design, Implementation, Integration, and Evaluation of Digital Health Systems to Enhance the Strategic Use of Data for Immunization Programming" to assess immunization service providers' acceptance and use of geospatial data for microplanning and routine immunization service delivery and associated effects on the vaccine coverage in DRC.

The generation of core geospatial layers is intended to provide key and timely insights for Health Zone and Provincial decision-makers to identify hard-to-reach settlements or settlements likely to fall in between two health catchment areas; estimate the population of the health areas and health zones; estimate a healthcare facility's catchment population; estimate the number of vaccines needed for a health area based on its population; assess the population coverage of current fixed vaccination strategies; optimize outreach vaccination strategies based on population distribution; and optimize the cold chain and new refrigerator allocation based on population distribution. The theory of change for M4H describes how the systematic generation and use of geospatial data and associated population distribution, including the identification of previously missed settlements, contributes to more effective immunization program planning and service delivery, which contributes to improved immunization coverage and equity. This theory of change was used to inform the development of the qualitative instruments (observation and interview guides developed by the research team), the intervention strength survey instruments, and the secondary analyses of immunisation coverage survey data.

Methods

This is a mixed-methods study with a quasi-experimental design focusing on the adoption, perceptions, and use of geospatial data for microplanning and routine immunization service delivery, and subsequent impact on vaccination coverage. Impact was assessed using a pre/post study design which draws upon the NEPI Vaccine Coverage Surveys (VCS) conducted in 2021 (for 2020 pre-intervention data), and repeated in 2023 (for 2021 and 2022 data); all surveys focus on children age 6–11 months and 12–23 months [9]. Efforts to assess impact were informed and complemented by qualitative research (direct observations and in-depth interviews) and intervention strength surveys in prioritized Health Areas in intervention and control sites to assess adherence to microplans with and without georeferenced data. A targeted rapid ethnographic study was conducted in Health Zones and Health Areas in Kasai which were exposed to gender-specific program activities. These sites were purposefully included in the intervention strength survey sample. The intervention strength survey and interview guides were developed in French by the research team and have been included as Supplementary Material.

The qualitative approach focused on interviews with various participants, including the Provincial Head of Division, NEPI branch Medical Chief, NEPI branch Data Managers, and the Analysts in charge of the health information to the Provincial Division, NEPI Monitoring and Evaluation Service Chief, and the person in charge of mapping in the National Health Information System (NHIS) Office at the central level. Interview guides were designed to facilitate the interviews with key informants.

In addition, a comparative descriptive analysis was performed to determine whether the use of geo-enabled microplans in Haut-Lomami is associated with significant differences in the percentage of zero-dose children aged 12–23 months post-intervention in the poorest and poorest economic strata between 2020 and 2021.

Setting

The study took place in 3 Provinces, namely Kasai (intervention site with gender component), Haut Lomami (intervention site without gender component), and Kasai Central (control site) illustrated in the Fig. 1 map. Prioritized survey sites included Health Zones that represent urban and remote areas. Our sample size was 113 health facilities in 98 Health Areas in 15 Health Zones in the three provinces as illustrated in Fig. 2.

For the sampling, we considered 30% of the total number of Health Zones for each stratum. To do this, we carried out simple random sampling using the Android application, "Randomizer". The same approach was used to select30% of the total number of Health Areas for each Health Zone. In the control Province, we used the same sampling method to select 15% of the total number of Health Areas for each stratum and 15% of the total number of Health Areas for each Health Zone.

Data collection

Data collection at Provincial and Health Zone levels took place from February to June 2023. The process involved in-depth interviews conducted in French and audio recorded and transcribed for qualitative analysis. The focus of these interviews was on the acceptance and use of geo-enabled microplans for immunization planning. A total of 19 in-depth interviews were conducted. Before each interview, the interviewers presented the objectives of the evaluation to the participants. Individual written informed consent was required and obtained from each respondent to participate in the study. Interviewers made appointments with each respondent, according to availability.

At Health Area and health facility levels, data collection techniques included: (1) a structured survey; (2) direct observation of maps and georeferenced microplans; (3) document review; and (4) semi-structured interviews with key informants. Quality control was carried out on an ongoing basis, at various stages of the study.

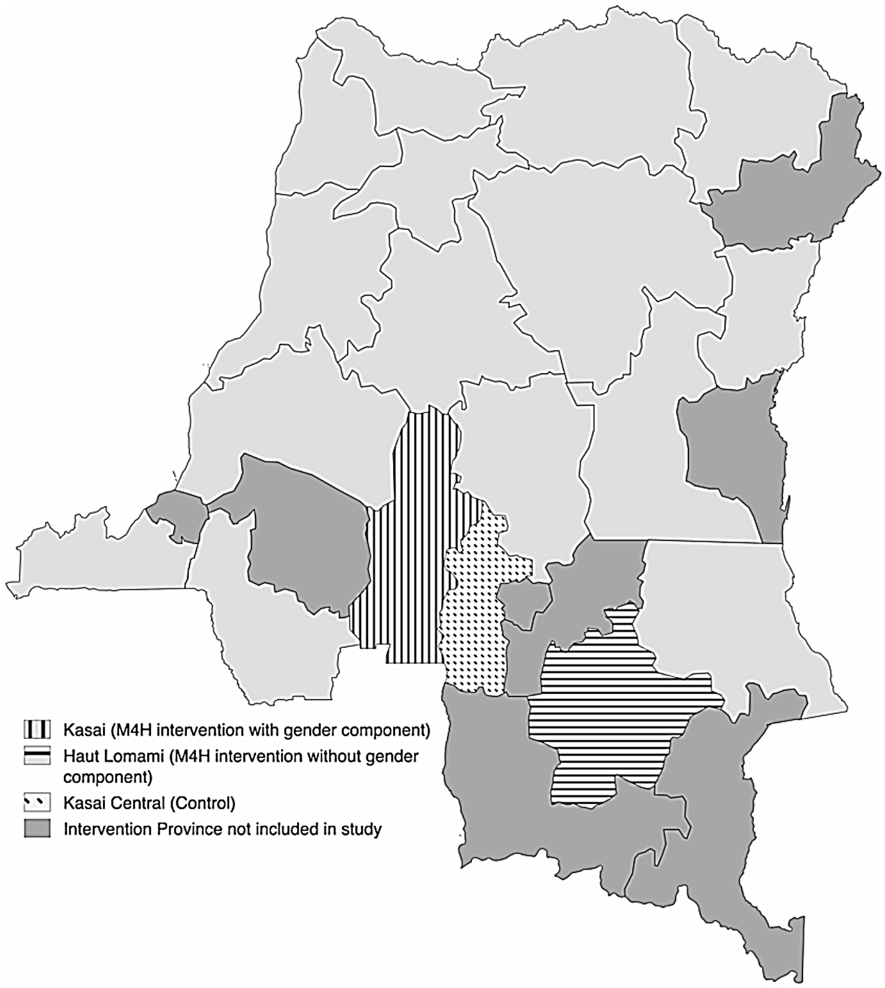

Fig. 1 Map of the Democratic Republic of the Congo showing intervention, study and control Provinces

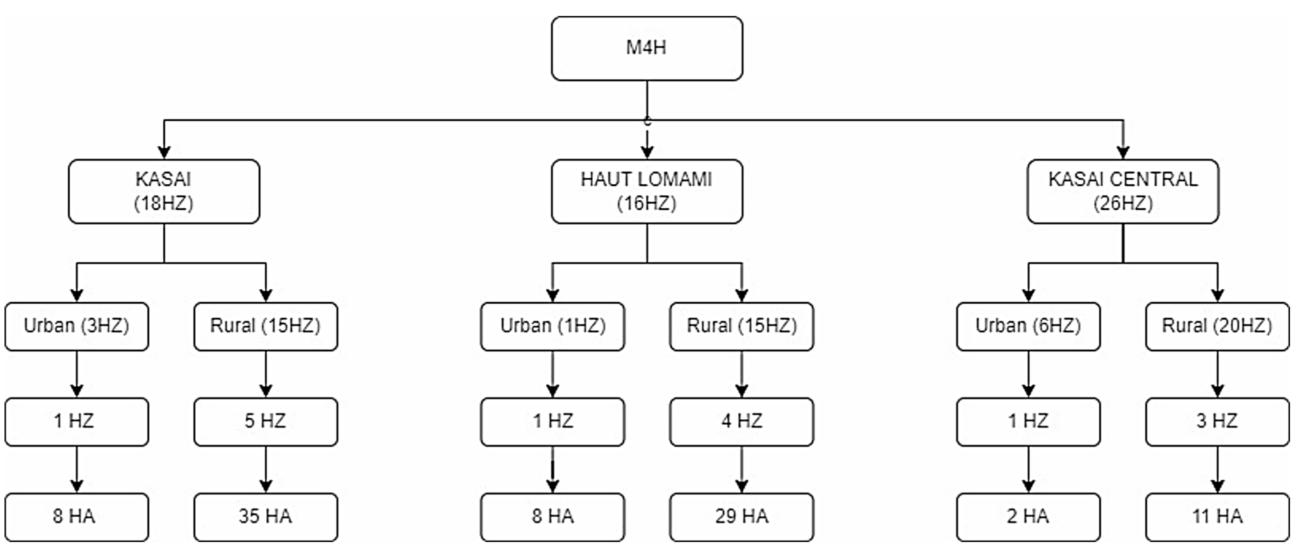

Fig. 2 Representation of the Sampling of Heath Areas. *HZ: health zone, HA: health area

Prior to the data collection

Interviewers with previous research experience were recruited among Kinshasa School of Public Health (KSPH) alumni (MPH degree) to guarantee data quality. The selection was based on their experience with this type of survey and on their availability for the period of this study. A two-day training was organized by province supervisors (academic assistants at the KSPH) focusing on the overall protocol of the study, its objectives, ethics measures to take into consideration, data collection using the Computer Assisted Personal Interview system, and adherence to different instruments. The questionnaire was digitized using SurveyCTO with automatic filters, constraints, and relevance criteria for certain questions to control data entry.

During and after data collection

The supervisor developed a follow-up plan for the field teams to ensure that the interviewers were in the various assignment zones. A supervision form was completed to report on field progress, including the number of interviews completed as well as any problems encountered in the field. All teams were linked by a WhatsApp group for rapid sharing of information in the field. Automatic checks of completed and sent questionnaires were carried out by the coordinator in charge of data processing and analysis. When necessary, the provincial supervisor was alerted to take corrective action. Data editing was carried out during data collection to ensure data quality, notably by searching for "I don't know" or "refusal" responses and by cleaning the database prior to the analysis.

Table 1 Socio-demographic characteristics of participants in the 3 provinces

	Haut-Lomami	Kasai	Kasai Central	Together
	n **= 46 (%)**	***n*** **= 49 (%)**	***n*** **= 16 (%)**	***n*** **= 111 (%)**
Sex				
Male	39 (85)	43 (88)	16 (100)	98 (88)
Female	7 (15)	6 (12)	0 (0)	13 (12)
Total	46 (100)	49 (100)	16 (100)	111 (100)
Age range				
< 25 years	1 (1)	0 (0)	0 (0)	1 (1)
25–34	15 (33)	5 (10)	5 (31)	25 (23)
35–49	18 (39)	26 (53)	9 (56)	53 (48)
≥ 50	12 (26)	18 37)	2 (13)	32 (29)
Total	46 (100)	49 (100)	16 (100)	111 (100)
Level of Study				
Secondary	13 (28)	15 (31)	4 (25)	32 (29)
Higher or University	33 (72)	34 (69)	12 (75)	79 (71)
Total	46(100)	46(100)	16 (100)	111(100)
Function				
IT (Head Nurse of Health center	17 (37)	44 (90)	8 (50)	69 (62)
IS (Health Zone Nurse supervisor in charge of immunization)	3 (7)	3 (6)	3 (19)	9 (8)
MCZ	0 (0)	1 (2)	0 (0)	1 (1)
Other	26 (57)	1 (2)	5 (31)	32 (29)
Total	**46 (100)**	**49 (100)**	**16 (100)**	**111 (100)**

Data analysis

The content of the in-depth interviews and open-ended survey questions was analyzed using ATLAS TI software. Through an inductive and iterative process, we used content analysis methods based on thematic codes and sub-codes. The initial list of codes was derived from the themes and questions contained in the interview guides. All transcripts were coded using the coding list. We looked for subgroups to highlight specific experiences and the reasons for those experiences.

The intervention strength survey data collected by the interviewers was transferred to the server after verification by the field supervisor. Secondary data cleaning was carried out using Survey CTO software. Data analysis was performed using SPSS Version 25 software. The data were analyzed to produce expected frequencies for categorical variables and continuous variables as well as the measure of central tendency (mean or median) and dispersion (standard deviation or interquartile range) according to the normality of the distribution. The Chi-square test was used to test for association, with an alpha of 0.05.

To assess the coverage and equity study objectives, secondary analyses of immunization coverage and equity survey data were conducted. The data extracted from the different VCS reports by the KSPH covered Haut-Lomami, Kasai, and Kasai Central. The extraction of the data was done manually. The variable measured was the percentage of children age 12–23 months who have not received any dose of Pentavalent vaccine to represent zero-dose prevalence or unvaccinated children. Additional quantitative analyses were carried out to further assess drop-out rates.

Results

Our findings are presented by study aims and objectives beginning with the socio-demographic characteristic of the interviewees (Table 1).

Most respondents were male (88%). The most common age group in all three provinces is 35–49 years age old with a total of 48% of all respondents interviewed. More than three out of four respondents had a higher or university degree. Three-fifths of respondents assumed the role of Head Nurse of Health center (62%), except in the Province of Haut-Lomami where slightly more than half were in other roles (57%).

Study Aim 1: program implementation context and mechanisms

Process through which geospatial data was created

Participation or contribution in the process The majority of study participants were not involved in the development of the design of the intervention. Differences in the engagement of the various stakeholders emerged, i.e., at the central level, not all the Ministry stakeholders had the same degree of participation or contribution to the intervention. At the provincial level, participation was in the planning and implementation phase. The interviewees noted that the intervention's objectives took account of the gender aspect from the point of view of the service providers and concrete implementation, as in the identification of vaccinated children by sex and age. For the equity aspects, they considered all social strata. The design of the georeferenced and gender data set-up was perceived to contribute to effective identification of where the targets are and informed the mechanisms to reach and vaccinate them according to NEPI guidelines. The project was also credited with resolving the problem of imprecise Health Area and Health Zone boundaries, as well as the location of populations overlooked during vaccination activities.

A content analysis by respondent category according to health system levels revealed a difference in perception of the gender and inclusion aspect. At the central level, the gender intervention was clearly known, and the various stakeholders recognized this dimension in the intervention and also contributed to it in the training aspects of the field teams. At the provincial level, the gender and social inclusion dimension was perceived differently by the various stakeholders.

Respondents confirmed that the community had taken part in the process through the community animation cells (CACs) with the agreement of the local authority, applying the principle that "whatever you do without me, you do against me". The Head Nurse of Health Areas organized briefing meetings to enlighten community members on the merits of mapping data. However, the community was perceived as both a barrier and an enabler. The result was mistrust on the part of the population in some communities, which were not accustomed to seeing sophisticated technological devices. In some Health Zones, the local population believed that they were being expropriated from their land, requiring repeated explanations despite prior authorization of the village chief. In some cases, the community resisted the activities outright.

As described by one of the respondents, "*In terms of ease of use, it's the community that knows the boundaries.... From a social point of view, you had to see the chief, because when you say, for example, "Where does your village end?" he's the one who should say, "My land goes as far as here". In terms of barriers, when we see an activity where we have to use fairly technological equipment, we wonder what the purpose is and that's the barrier or reticence that we could feel". (Head Nurse, Kasai).*

The contribution of the community extended to the feedback it provided for the validation of mapping data collected, even if community leaders (CAC) are still expecting to receive updated maps with corrected information, where needed. With regard to gender, the main reflection of key informants was that Health Zone management teams take into account the gender dimension in the current immunization register, where vaccinated children are well identified by age and sex.

Mapping acceptance, challenges, and prospects The mapping was well accepted by various stakeholders. Positive aspects include the production of better-quality maps, enabling more accurate location of sites compared with the old handwritten maps along with the production of more accurate population estimates and population densities, enabling better planning of vaccination activities. Negative aspects were related to the imperfection of the maps, which had some omissions or inaccuracies of specific customary landmarks. For certain Health Zones, some Health Areas had almost disappeared, for which the respondents wanted the maps to be updated.

On the optimal future for the mapping, one respondent commented: "*It's a promising future, but it's only the first step. I think that these will be dynamic maps that can be updated as we go along.... So, the project will have to see how to establish a certain periodicity for updating these maps". (NEPI* branch office, *Haut-Lomami).*

Process through which project georeferenced data is shared for use in microplanning

Many of the respondents have worked for more than 10 years, directly or indirectly, in the microplanning of routine immunization activities using a paper-based microplanning process. They are therefore experienced resources in this field, from the Head Nurses and the community (community relays, community animation cells and health development committees) who took an active part in the microplanning of their respective Health Areas and transmission to Health Zone central office level.

The following considerations were perceived as facilitators for the use of geospatial data for microplanning and routine immunization: the existence of a legend that makes it easy to read a map; attraction to technology; transition from analogue to digital; the desire to do things differently and better; users were involved in the process; user support; buy-in and use of the tool by the service provider.

For some Health Zones, the following were perceived as obstacles: the problem of connecting to the Internet; lack of knowledge of the tool; lack of training; unavailability of logistical and financial resources; most of the tools used in vaccination are paper-based; most of the tools are intended for people who are not too literate in terms of technology; technological tools require a substantial investment; old habits; other logistical, financial and economic constraints in implementation.

Process through which geospatial data is used as part of microplanning processes

All Health Zones as well as all Health Areas surveyed in the Kasai Province (49/49 health facilities) received the georeferenced data. Almost the entire Haut-Lomami Province, 98% (45/46), received the georeferenced data; no georeferenced tools were received in Kasai Central Province (16/16), which is the control Province. At the time of the study, different maps generated by the project were observed by the research team to be taped to the office walls of almost all (98%; 48/49) of the health facilities investigated in the Kasai Province and 70% (32/46) of the walls of the Haut-Lomami Province. Unanimously, respondents mentioned their satisfaction and affirmed that the maps were an important addition in general and that their use in vaccination activities made it possible to improve their knowledge and acquire more information on the respective entities. This also made it possible to resolve conflicts over the delimitation of the geographical boundaries of the Health Areas, since in some cases, the limits defined on these tools did not reflect the reality on the ground.

Overall, microplanning tools are displayed by the Health Area Head Nurses in 83% of the health facilities visited: respectively 89% (41/46) and 86% (42/49) in the two provinces of intervention of Haut-Lomami and Kasai, and 63% (10/16) in the control province of Kasai Central. Almost all microplanning tools (98%) were in paper format. The microplanning tool is accessible in most cases to full-time nurses in 88% and to other nurses in 39% of the health facilities visited.

In the two intervention Provinces, the main users of the microplanning tool are the health center nurses in 92% of cases compared to 75% in the control Province. Before the introduction of georeferenced data, half of the health facilities in Haut-Lomami used data from the NEPI Program (51%) when developing their microplans, while more than four-fifths of Kasai Province (86%) and half of Kasai Central health facilities (50%) respondents reported using routine data.

In the two intervention Provinces, 84% of health facilities are now using the georeferenced estimates of the target population, its distribution by site or location (78%), the identification of the sites of vaccination (76%), the identification of vaccination sites for optimizing vaccination strategies, i.e., outreach strategy (63%) and the identification of new villages (62%), as presented in Table 2.

According to the qualitative analyses, respondents, particularly at the Health Zone and provincial levels, indicated that support for vaccination activities has significantly improved with the introduction of geospatial data. Apart from the numbers of the target populations which experienced variation in the direction of increase (Kasai Province) or decrease (Haut Lomami Province), other data from the Health Areas in terms of the number of settlements, fixed or advanced sites, neighborhoods remained almost the same before and after of the introduction of geospatial data.

Process through which geospatial data is used as part of routine immunization programme implementation

Almost all (94%) of health facilities in the intervention provinces use geospatial data for routine immunization programme implementation in their Health Areas. This use is more pronounced in the Haut-Lomami Province (96%) compared to that of Kasai (92%).

The interviews unanimously emphasized that georeferenced data was important in the planning process. They made it possible to improve information relating to the different vaccination strategies (e.g. fixed, outreach, mobile), the number of vaccines to order, the availability and location of refrigerators, and the size of the population to be covered in the context of vaccination activities. A small group of respondents reported that the use of geospatial data made it possible to improve distribution in terms of the number of vaccines to be requisitioned according to consumption.

Most respondents (69%) declared that the geospatial enabled tools are very easy to use. More than three quarters are at least satisfied with the information contained in the tool and its use in activity planning. Most respondents agreed that the geospatial tool has reduced their working time and improved data quality, as shown in Table 3.

According to the qualitative results, respondents unanimously stated that the tool had more advantages than disadvantages. One of the most significant benefits mentioned by respondents is reaching zero-dose children in each Health Area. At the provincial level, the tool helped improve the planning, implementation, and supervision of vaccination activities.

Table 2 Distribution of microplan users and reported georeferenced data and uses

	Haut-Lomami	Kasai	Kasai Central	Together
	Num (%)	Num (%)	Num (%)	Num (%)
Microplan Users				
IT (Head nurse of Health center)	41(91.1)	45(91.8)	12(75.0)	98(89.1)
Male nurse	23(51.1)	15(30.6)	1(6.3)	39(35.5)
RECO (community relay)	14(31.1)	11(22.4)	1(6.3)	26(23.6)
Others	2(4.4)	17(34.7)	2(12.50)	21(19.1)
IS (Supervisor Nurse in the Health zone in charge of immunization)	5(11.1)	5(10.2)	6(37.5)	16(14.5)
MCZ (Health Zone Chief medical doctor)	4(8.9)	3(6.1)	3(18.8)	10(9.1)
What was the source of information before Georeferenced data?				
Routine data *	18(40.0)	42(85.7)	8(50.0)	68(61.8)
National EPI **	23(51.1)	2(4.1)	6(37.5)	31(28.2)
Other (s) to be specified	4(8.9)	5(10.2)	2(12.5)	11(10.0)
Type of georeferenced data included in the tools				
Target population (new denominator)	38(84.4)	43(87.8)	N / A	81(84.5)
Distribution of the target population by site or location (number)	34(75.6)	43(87.8)	N / A	77(77.3)
Identification of vaccination sites	34(75.6)	34(69.4)	N / A	68(72.7)
New villages, neighborhoods, hamlets and/or camps identified (on the map)	34(75.6)	32(65.3)	N / A	66(69.1)
Identification of outreach strategy vaccination sites	30(66.7)	32(65.3)	N / A	62(64.5)
Other (s) to be specified	8(17.8)	13(26.5)	N / A	21(20.9)
Seasonal movement of the target population	11(24.4)	6(12.2)	N / A	17(16.4)
What planning need is solved with Georeferenced Tools?				
Location of the target population	39(86.7)	45(91.8)	N / A	84(89.4)
Number of doses to plan	26(57.8)	37(75.5)	N / A	63(67.0)
Reliable denominator	20(44.4)	18(36.7)	N / A	38(40.0)
Others	7(15.6)	11(22.4)	N / A	18(19.1)
Georeferenced data actually used as reported by microplan users				
Target population	37(82.2)	42(85.7)	N / A	79(84.0)
Distribution of the target population by site or location	32(71.1)	41(83.7)	N / A	73(77.7)
Identification of vaccination sites	35(77.8)	36(73.5)	N / A	71(75.5)
Identification of outreach strategy vaccination sites	32(71.1)	27(55.1)	N / A	59(62.8)
Identification of villages, neighbourhoods, hamlets, camps (mapping)	31(68.9)	27(55.1)	N / A	58(61.7)
Seasonal movement of the target population	2(4.4)	10(20.4)	N / A	12(12.8)
Others	4(8.9)	3(6.1)	N / A	7(7.4)

Legend: * Routine data: Data collected at local level by the health zone; ** Population estimates data provided by the NEPI at central level

Acceptance and perceptions of gender intervention with geospatial data use in Kasai

Interviews with all gender training participants (14/14) in the targeted Health Zones in Kasai Province revealed that this was a good training course focusing on gender considerations. Field teams are now starting to disaggregate data in terms of gender and increase women's participation as vaccinators. Knowledge of vaccination teams has improved, and gender principles were included in vaccination activities and complimented the geo-enabled microplans for better immunization coverage.

Most of the community members who took part in this study recognized that the gender training helped them to solve problems linked to inequality and discrimination between men and women in the community, starting with immunization but also more generally. All the participants in the interviews recognized that now, some women are involved in vaccination activities in the community. As noted by a participant: "*I too find that gender or parity has helped a lot, even at the level of vaccination teams. Back then, it was mainly men who went around vaccinating children in the Health Area. Now, we also see women giving vaccines, this has brought about a change in the community". (Gender intervention respondent).*

However, the ratio of women to men in the health system is still low, and many participants felt that all the authorities should enhance women's capacities and skills, as they are able to contribute to strengthened immunization services in the community. A key informant noted, "*In our Health Zone, there is no female managing the CODESA [Comité de Développement de l'Aire de Santé / Health Area Development Committee]. All the twenty-eight are men. So, we've made a plea to our partners to help us revitalize the CODESAs, to see where there are*

Table 3 Distribution of participants according to satisfaction with informational content and use of georeferenced tool

	Haut-Lomami	Kasai	Kasai Central	Together
	n= (%)	n= (%)	n= (%)	n= (%)
Is the tool easy to use				
Easy to use	34 (75.6)	31(63.3)	N / A	65 (69.1)
Very easy	5 (11.1)	13 (26.5)	N / A	18 (19.1)
Not easy to use	4 (8.9)	5(10.2)	N / A	9 (9.6)
Easy enough	2 (4.4)	0(0.0)	N / A	2 (2.1)
Are you satisfied with the information contained in the georeferenced microplanning tool?				
Satisfied	26 (57.8)	33(67.3)	N / A	59 (62.8)
Very satisfied	13(28.9)	11(22.4)	N / A	24 (25.5)
Somewhat satisfied	3 (6.7)	5(10.2)	N / A	8 (8.5)
Unsatisfied	3 (6.7)	0(0.0)	N / A	3 (3.2)
Are you satisfied with using this tool?				
Satisfied	26 (57.8)	33(67.3)	N / A	59 (62.8)
Very satisfied	13(28.9)	12 (24.5)	N / A	25(26.6)
Somewhat satisfied	5 (11.1)	3 (6.1)	N / A	8 (8.5)
Unsatisfied	1 (2.2)	1 (2.0)	N / A	2 (2.1)
The reason for not being satisfied with the information contained in the microplan				
Too long	3 (100)	0(0.0)	N / A	3 (100)
Difficult to use	3 (100)	0(0.0)	N / A	3 (100)
Contribution of microplanning tool in reducing working time				
All right	22 (48.9)	26(53.1)	N / A	48 (51.1)
Totally agree	10 (22.2)	17(34.70)	N / A	27(28.7)
Disagree	7 (15.6)	2(4.1)	N / A	9 (9.6)
Fairly agree	6 (13.3)	3 (6.1)	N / A	9 (9.6)
not agree at all	0(0.0)	1 (2.0)	N / A	1 (1.1)
Will the microplanning tool improve the quality of your data				
All right	30 (66.7)	31(63.3)	N / A	61 (64.9)
Totally agree	10 (22.2)	13(26.5)	N / A	23 (24.5)
Fairly agree	3 (6.7)	2(4.1)	N / A	5 (5.3)
Disagree	1 (2.2)	3(6.1)	N / A	4 (4.3)
not agree at all	1 (2.2)	0(0.0)	N / A	1 (1.1)

shortcomings so that we can get back on track with competent women". (Gender intervention respondent).

How does gender affect health workers' use of mapping and georeferenced data?

Most respondents acknowledged that this focus on gender has enabled them to put into practice this new strategy involving women and men in microplanning, awareness-raising, and mobilizing mothers for immunization. They also noted that complementarity between women and men is essential to reach zero-dose children and children lost to follow-up or incompletely vaccinated children in the community.

For the gender distribution in training on the production of spatial maps and estimates of vaccination target populations, interviews revealed that in each Health Zone, there were a total of twenty (20) people, fifteen (15) women, and five (5) men. It was clear that all the women had carried out the process of capturing data with geospatial tools, so that they could have the matrix to demonstrate to the other members of their community.

However, respondents noted that service delivery is impacted by deep-rooted social and cultural norms concerning the roles and responsibilities of men and women, constituting challenges, obstacles or barriers to immunization which can affect both caregivers and health workers, and negatively influence the provision, demand and use of immunization services.

Geospatial data use with a gender lens

Regarding the impact of gender on health workers' immunization planning and conduct of routine immunization activities, most of the respondents revealed that today, immunization campaigns are prepared using telephones, which means that health workers have a very good grasp of the boundaries of their Health Areas, as well as the targets to be immunized in the Health Area. They noted that the representation of men and women facilitated the participation and complementarity of all health workers in all upstream and downstream activities to achieve good results. One participant pointed out that "*in terms of vaccination, for example, you'll find that when a woman administers the vaccine, people are so happy. So, there are always positive influences". (Gender intervention respondent).*

The gender-intentional training as part of the georeferenced microplan development process has contributed to re-evaluating the composition of vaccination teams, namely the CODESA and CAC teams, supporting women to achieve good results to reach and vaccinate all the children expected. To this end, most respondents indicated that all providers (women and men) work together to achieve targets.

Study Aim 2: associated effects of the acceptance and use of georeferenced data by health zones and health areas on immunization coverage and equity

For the second study aim, a quasi-experimental design study in the three provinces was used to determine the associated effects of the acceptance and use of geospatial data on immunization coverage and equity. The secondary data analyses were based on data from the immunization coverage and equity surveys of children 12–23 months of age.

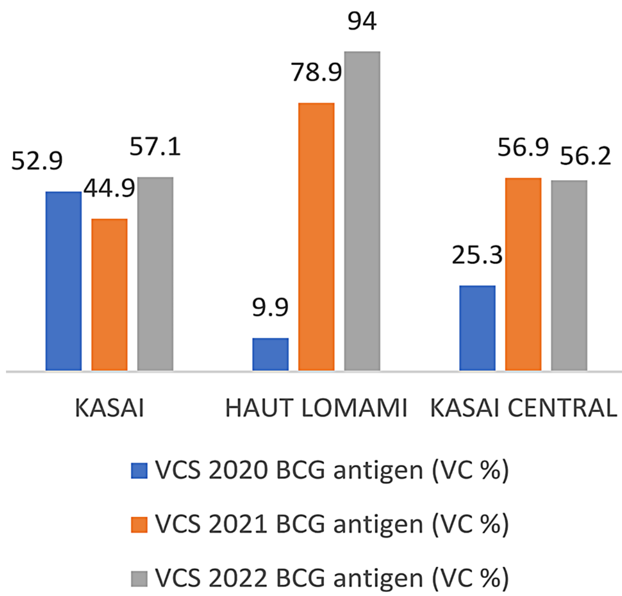

Fig. 3 Estimates of BCG antigen vaccination coverage for children aged 12 to 23 months. Point estimates of BCG antigen vaccination coverage indicators according to the vaccination map for children aged 12 to 23 months in the provinces of Kasai, Kasai Central and Haut-Lomami in the DRC in 2020, 2021 and 2022. **Source**: VCS in DRC: 2020, 2021 and 2022 [9]

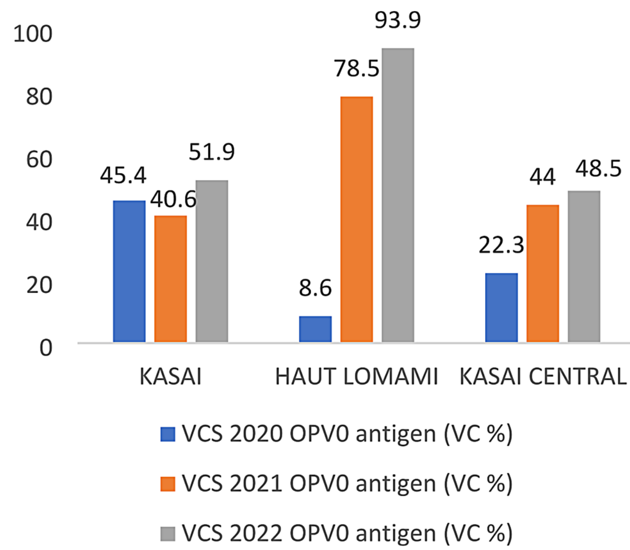

Fig. 4 Estimates of OPV0 antigen vaccination coverage for children aged 12 to 23 months. Point estimates of OPV0 antigen vaccination coverage indicators according to the vaccination map in children aged 12 to 23 months in the Provinces of Kasai, Kasai Central and Haut-Lomami in the DRC from 2020, 2021 and 2022. **Source**: Vaccination coverage survey (VCS) in DRC: 2020, 2021 and 2022 [9]

It is important to note that the intervention had not been implemented for a sufficient time in Kasai to contribute to significant improvements in immunization coverage or equity. Georeferenced tools were distributed in Kasai in 2023 and would need at least 12 months of implementation to contribute to substantial changes in immunization outcomes. Thus, for this part of the study, Kasai was also considered as control with Haut Lomami as the unique intervention site.

Changes in immunization coverage and loss to follow up after at least 12 months of implementation

Secondary data analysis of Bacillus Calmette–Guérin (BCG), Oral Polio Virus (OPV) 0 and Pentavalent vaccination coverage from the 2020, 2021 and 2022 VCS in the three Provinces show some marked improvement in the intervention Province during the period of implementation with stagnation in other two sites [9].

Coverage surveys show improvements in BCG vaccination coverage in the intervention Province of Haut-Lomami Province (9.9% (2020), 78.9% (2021) and 94% (2022)). Kasai Central (control Province) saw some improvement in BCG coverage between 2020 and 2021 (25.3% in 2020 to 56.9% in 2021) with stagnation in 2022 (at 56.2%). Kasai (control Province) showed an improvement in BCG antigen coverage, with a "V"-shaped evolution over the three years, i.e. a drop from 52.9% in 2020 to 44.9% and then an improvement to 57.1% in 2022. (Fig. 3).

The trend for OPV 0 is similar to that observed with BCG, with large improvements in coverage in the intervention Province of Haut-Lomami and moderate improvements or stagnation in the control Provinces of Kasai Central and Kasai (See Fig. 4).

For Pentavalent 1 antigen, the VCS data show a large increase in coverage in Haut-Lomami Province (Intervention) across the 3 time points (9.9% in 2020 to 78.5% in 2021 and 93.6% in 2022). For the two control Provinces, the rate saw more modest net improvements at the third timepoint. For the 3rd dose of Pentavalent, the vaccine coverage rate also showed a significant improvement for Haut-Lomami with similar drop-out rates across the 3 timepoints indicating stability within the immunization program. In the two Control Provinces of Kasai and Kasai Central there was a net increase in the dropout rate between Penta 1 and Penta 3, indicating a decline in the immunization program's follow-up with children who started the vaccination schedule (See Table 4).

It emerged from interviews that in general, the use of georeferenced data made it possible to improve involvement of health facilities that have not offered immunization services and consequently to reach children who missed vaccination days. In addition, this made it possible to improve the vaccination catch-up which was carried out previously by the community relays to reach zero-dose children. A nurse stated the following: "*You know a health facility which 15 kms far away from a health center and does not vaccinate. If for example the nursing staff of a health center starts moving with vaccines to the health facility that does not vaccinate, when*

Table 4 Estimates of Penta 1 and 3 vaccination coverage ages 12–23 months

Provinces	VCS 2020			VCS 2021			VCS 2022		
	Penta1 (%)	Penta 3 (%)	Drop-out rate (%)	Penta 1 (%)	Penta 3 (%)	Drop-out rate (%)	Penta 1 (%)	Penta 3 (%)	Drop-out rate (%)
Kasai VC (%) CI 95%	51.0 (46.6–55.4)	45.3 (41.2–49.4)	5.7	48.1 (44.3–51.8)	34.4 (30.8–38.2)	13.7	58.3 (53.3–62.0)	38.0 (33.4–42.6)	20.3
Haut-Lomami VC (%) CI 95%	9.9 (7.1–13.6)	8.9 (6.3–12.6)	1.0	78.5 (73.3–83.0)	76.8 71.4–81.4)	1.7	93.6 (92.0-94.9)	92.0 (90.4–93.8)	1.6
Kasai Central VC (%) CI 95%	26.3 (23.6–29.2)	21.8 (19.3–24.6)	4.5	61.1 (57.4–64.6)	47.2 (43.2–51.2)	13.9	59.3 (55.7–62.9)	43.8 (40.7–47.9)	15.5

Legend: Point estimates of Penta 1 and 3 vaccination coverage indicators in children aged 12 to 23 months in the 3 provinces of the study in 2020, 2021 and 2022. Source: VCS in DRC: 2020, 2021 and 2022 [9]. VC: Vaccine Coverage; CI: Confidence Intervals

they arrive there, you will see all these children who were zero dose will come to be vaccinated and even this health facility will also be interested in vaccination. So, it does influence positively the reduction of zero doses and even the involvement of other types health facilities in vaccination." (Respondent; Health Area, Haut-Lomami).

However, in Kasai, some respondents reported difficulties linked to recurrent population movements. This creates challenging in locating target children with the consequence of uneven vaccination coverage. For example, one respondent said: "*The obstacles that we often experience is movement, we are in a purely mining Health Zone where the population is moving all the time.*" (Respondent _09, HA, Kasai).

Impact of geospatial data on equity

The impact of geospatial data on equity was assessed in terms of reaching the most marginalized children 0–23 months (girls/boys) and the main caregivers - women and adolescent girls in their reproductive years (15–49 years of age). However, because of the unavailability of economic data, the ability to conduct robust equity analyses was limited. The results of the equity analyses were inconclusive, and therefore, not presented here. They have been included in the comprehensive research report provided as Supplementary Material.

Discussion

The study aimed to assess the acceptance and use of geoenabled microplans for better immunization planning and services delivery. It tested the hypothesis that the availability and effective use of geospatial data can contribute to increased immunization coverage and equity, through the identification of missed settlements and zero-dose children, the optimization of vaccination strategies, and the supply distribution. It also incorporated a gender-sensitive approach and included a gender substudy to assess gender-specific interventions in a sub-set of Health Zones and Health Areas in Kasai, as part of Gavi's intensified strategy to address gender inequity and the global Immunization Agenda 2030 focus on gender [1–3].

The results indicate that the georeferenced microplans in Haut-Lomami and Kasai were well received, used, and led to changes in the planning and delivery of vaccination services. As an innovation, the context and mechanisms through which geospatial data and tools were created and accepted for use confirmed their importance and effective adoption at Health Zones and Health Areas. As found in Haut Lomami, geospatial data enabled the visualization and analysis of health data in spatial contexts, offering insights into the geographical distribution of the population, health area boundaries, healthcare facilities and immunization coverage. In line with our results, it has been largely documented that Geospatial Information Systems (GIS) and other geospatial technologies facilitate targeted interventions, allowing health authorities to optimize and enhance the precision of resource allocation in resource-constrained settings and identified underserved areas to allocate resources efficiently in specific geographic areas [10–15].

The potential of GIS and spatial analysis to enhance the effectiveness of health providers and monitor immunization coverage has been emphasized in other Central African countries [16–19]. The evaluation of immunization coverage in Haut Lomami before and after the availability of geospatial data have shown that these tools may have contributed as one component of a broader set of immunization strategies to significant increases in immunization coverage rates and lower dropouts, including reduced numbers of zero-dose children. These results corroborated with other studies in the context of LMICs [5, 13, 17]. Additional study with a longer observation time, i.e., more than three years, is recommended in Kasai to triangulate findings from Haut-Lomami and assess the additional contribution of gender-intentional approaches to improved immunization outcomes. However, to be fully effective, the production and use of geospatial data and maps need more work to build capacity and ensure the quality of data and maps, as persistent challenges in data quality, such as inflated coverage figures and inaccurate denominators, remain significant hurdles [7, 16, 20, 21]. Qualitative research in the 2 intervention Provinces included in this study show that gaps remain in the protocols for validating the data with the community and making regular updates in the datasets. There is room for improvement to boost the acceptance, quality and effective use of the geo-referenced microplans through meaningful community engagement, capacity building and digital literacy training for end users.

The drastic improvements in immunization outcomes in Haut-Lomami may be also explained by other factors, such as the parallel implementation of some specific immunization projects, which worked in synergy. The Province of Haut-Lomami has been a Mashako Plan site with intensified support of the NEPI [4, 22]. In addition, an intervention aiming to improve the distribution of vaccine products up to the last kilometer and using Information and Communication Technologies in the fields of health has intensively assisted the Province through the NEPI branch office of Kamina [22, 23]. We are unable to attribute the full increase observed for the Penta3 vaccine between 2020 and 2021 (from 8.9% in 2020 to 76.8% in 2021) to the adoption and use of geospatial data alone and acknowledge that it may be an important part of a larger package of strategic NEPI interventions.

Taking a gender lens for the overall study, we identified perceived positive contributions to the intervention and the evaluation. In the delivery of immunization services, it is important to include transformative and equitable gender strategies, taking into account the socio-cultural contexts in which health workers and caregivers live and work. Gender mainstreaming must be carried out at all levels of microplanning design and implementation, in the use of georeferenced data, in conducting routine immunization, and in monitoring and evaluation. To achieve this, awareness and action is needed at national and sub-national levels to conduct gender analyses and design gender-sensitive interventions to reduce gender-related barriers to immunization and georeferenced data use. Targeted interventions based on spatial analysis effectively reduced disparities, promoting a more equitable distribution of immunization services, that address specific barriers faced by vulnerable populations [13, 24–26]. Due to the lack of availability of robust data that would enable the assessment of effects related to equity, we were unable to compare results beyond those associated with the reduced rate of zero-dose children detected in Haut-Lomami Province. However, to tackle inequities in immunization, for over a decade countries have been focusing on effective immunization microplans at the subdistrict level, using georeferenced data and maps for better planning of immunization activities, such as community-based Reach Every Child (REC) intervention [11, 12, 25–28].

Limitations of the study

Overall, while our study is in line with the recent literature and demonstrates the positive contribution of geospatial data on immunization outcomes, challenges persist. The intervention did not allocate sufficient resources and time for socialization and capacity building to promote the adoption and effective use of the maps, geospatial data and geo-referenced microplans. This was compounded by delays from the COVID outbreak that impacted the overall routine immunization program and limited community engagement in the mapping process and created a gap between the collection and generation of the geospatial data and the distribution and adoption of the geospatial resources. Additional challenges are inherent in the design of the intervention that optimizes strategies based on population distribution. By targeting areas with higher populations for improved immunization delivery strategies, areas with lower populations may not benefit from improvements in immunization coverage at the same rate. While the overall goal is to reach high childhood immunization rates in all geographic areas for all populations, tradeoffs are often necessary especially in the implementation of new strategies and technology approaches. Future implementation research should focus on overcoming these challenges, optimizing the use of geospatial data into immunization strategies in all health facilities, and expanding gender-sensitive approaches across the full NEPI.

This research study faced constraints and limitations due to delays in project implementation that resulted in a shortened period between implementation, distribution and adoption of the maps in health facilities and the research data collection, preventing the ability to observe impact on immunization outcomes for the recommended 12–24 month period. A follow-up study to measure longer-term outcomes is in the planning stages. The study was also not able to calculate cost-effectiveness, conduct costing analysis or determine the impacts on socio-economic equity due to the unavailability of these data from external surveys. Since the quantitative pre/post data relied on secondary analysis of VCS survey reports, the study was not able to include more detailed analysis of vaccine cards and memory recall.

Conclusion

The situation of zero-dose children in the DRC is a major concern. The overall objective of the study was to evaluate the acceptance and use of geo-enabled microplans for the planning and delivery of routine immunization services, and the associated contribution to increased and sustained immunization coverage with a focus on the identification and vaccination of zero-dose children. The results indicate that the georeferenced microplans in Haut-Lomami and Kasai were well received, used, and led to changes in planning for and delivery of vaccination services. In addition, the gender ethnographic study in Kasai indicates that the gender intervention led to the greater inclusion of women in immunization activities. We observed a significant positive trend in Haut-Lomami in immunization outcomes, including an increase in overall vaccination coverage and improved identification and immunization of zero-dose children. Due to the delayed time of georeferenced microplan adoption and use, a supplemental study to follow the implementation in Kasai in 2024 and 2025 for further immunization coverage and equity analyses is planned.

In general, this research study revealed important lessons for the design and implementation of geospatial data programs for immunization program planning. Community engagement and a gender-intentional approach throughout the planning, data and map creation processes are valuable to increase impact and effectiveness. More attention should be paid to economies of scale and seek out opportunities for cross-sector investment in geospatial data sets which can be foundational assets across national priorities, not only for the immunization program. Capacity strengthening for people involved in the creation and use of geo-referenced microplans as well as a long-term plan for maintaining and updating the data should be embedded in the project from the beginning.

Abbreviations

BCG	Bacillus Calmette–Guérin vaccine
CAC	Cellule d'Animation Communautaire (Community Animation Cells)
DRC	The Democratic Republic of Congo
CODESA	Comité de Développement de l'Aire de Santé (Health Area Development Committee)
DTP1	Diphtheria–tetanus–pertussis containing vaccine, first dose
Gavi	Gavi, the Vaccine Alliance
GIS	Geographic Information System
GRID3	Geo–Referenced Infrastructure and Demographic Data for Development
KSPH	Kinshasa School of Public Health
LMIC	Low–and middle–income country
M4H	Mapping for Health
NEPI	Expanded Program on Immunization
NHIS	National Health Information System
OPV	Oral polio vaccine
VCS	Vaccine Coverage Survey
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-21578-x.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

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Author contributions

DNB is the Principal Investigator and led the research on behalf of the KSPH. PM led the overall research design and publication process on behalf of health.enabled. FK, TB, GL, FL, KL, and MK supported the research design, field research, report and publication writing with the KSPH. BK provided overall support for research activities in DRC on behalf of health.enabled. KT provided inputs into the research study and review of findings on behalf of the implementation partner, Columbia University. CL reviewed the findings of the research study on behalf of National Expanded Program on Immunization. CG provided overall guidance for the research study and review of findings on behalf of Gavi, the Vaccine Alliance.

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Data availability

Data is provided within the manuscript and can be requested via email to ngobebed@gmail.com.

Declarations

Ethics approval and consent to participate

The Mapping for Health Study has been reviewed and cleared by the Kinshasa School of Public Health Internal Review Board. The research team obtained informed written consent from all study participants prior to their engagement in the research study. The study has also been registered with BMC Central International Standard Randomised Controlled Trial Number ISRCTN65876428 on 3/11/2021.

Consent for publication

All human subjects have provided informed written consent to participate in the study and for results to be published. All co-authors have reviewed the paper and agreed to have it submitted for review and publication.

Competing interests

The authors declare no competing interests.

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