

1 **Distance matters: barriers to antenatal care and safe childbirth in a migrant population on**  
2 **the Thailand-Myanmar border from 2007-2015, a pregnancy cohort study**

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51 **Abstract** (250 words)

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I. Background

Antenatal care and delivery with skilled attendants substantially improve maternal health outcomes across the pregnancy spectrum, from conception to delivery. The Sustainable Development Goals recognize the need to expand these services to all pregnant women but there is limited data on access for migrants and in post-conflict regions.

II. Methods

Using geographic information systems established for malaria elimination efforts in Kayin state, Myanmar and Tak Province, Thailand, retrospective estimates of travel distances from home villages to maternal health facilities between 2007-2015 were made. Multivariable regressions were used to assess the relationships between distance to healthcare and 1) presentation for early pregnancy care, 2) complications during pregnancy like malaria infections, and 3) eventual outcome of the pregnancy.

III. Findings

Women who delayed antenatal care until the third trimester travelled 46% farther (DR: 1.46; CI: 1.39 – 1.53) compared to women who attended in the first trimester, and those with pregnancies complicated by *Plasmodium falciparum* malaria travelled 62% farther (DR: 1.62; CI: 1.44 – 1.82) than those without *P. falciparum*. Women did not deliver with skilled birth services and were lost to follow-up travelled 45% farther (distance ratio (DR): 1.45; CI: 1.40 – 1.51) than those who followed-up to deliver with skilled birth services.

IV. Interpretation

This analysis supports substantial global evidence that travel distance disrupts access to care in limited resource regions. This is the first demonstration of empirical distance impacting maternal healthcare from early pregnancy to delivery of migrants living in post-conflict Thailand-Myanmar border regions, and future interventions should provide decentralized maternal healthcare to address these barriers.

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## 94 INTRODUCTION

95 For over 50 years civil war in Kayin state, Myanmar has forced hundreds of thousands to flee  
96 their homes and resettle either in the relative security of the Thai/Myanmar border region or to a third  
97 country.<sup>1</sup> Peace talks began in 2013, but the legacy of the civil war continues to manifest in the region. A  
98 lack of public health infrastructure limits accessibility for those who remain in Myanmar,<sup>1</sup> and language  
99 barriers and a lack of official immigration status prevents the many people who seek employment in  
100 Thailand from accessing services run by the Thai healthcare system. Although health data for this  
101 conflict-displaced population has been difficult to collect, what has been gathered indicates a high burden  
102 of poor pregnancy outcomes, mostly driven by conditions that can be reduced or prevented through  
103 routine antenatal care and skilled birth attendants.<sup>2</sup>

104 WHO-approved interventions across the pregnancy spectrum (Figure 1), from early pregnancy  
105 care during the first trimester to delivery in the presence of skilled birth attendants in the third trimester,  
106 have been shown to improve pregnancy outcomes.<sup>3</sup> A growing body of literature, mainly focusing on  
107 low-income and resource-limited settings, has shown that geographic distance to maternal health facilities  
108 influences women's use of those facilities. A systematic review of west African countries found that  
109 travel distance was a key predictor of maternal healthcare services<sup>4</sup>, and a prospective cohort study in  
110 rural Rwanda found that distance from delivery services significantly predicts the use of skilled birth  
111 attendants, but does not affect the number of visits women make to antenatal care facilities.<sup>5</sup> The majority  
112 of evidence comes from cross-sectional studies in Cameroon, Rwanda, Ethiopia, China, Burkina Faso,  
113 and Ghana, which indicate that distance to healthcare facilities is a major determinant of the use of  
114 maternal healthcare services.<sup>6-10</sup> Notably, a spatial analysis from Kenya found that distance did not  
115 always correlate with use of antenatal care, which highlights how the effect of distance on uptake of  
116 maternal healthcare can vary across a region.<sup>11</sup>

117 Distance has also been shown to correlate with delays in seeking care for pregnancy  
118 complications<sup>12</sup> and receiving timely treatment for emergent conditions.<sup>13</sup> Further, facility births where  
119 skilled attendants can provide emergency obstetric and newborn care are also reduced by greater distance  
120 to the health facility in low-income countries or marginalized communities<sup>5,14</sup>. Even a one kilometre  
121 increase in travel distance has been shown to reduce use of skilled birth attendants by 6.7%.<sup>15</sup> In the Thai-  
122 Myanmar border region, however, the relationship between geographic distance, loss to follow-up, and  
123 poor pregnancy outcomes has yet to be examined.

124 The Shoklo Malaria Research Unit (SMRU) operates a system of antenatal clinics (ANCs) and  
125 skilled birth facilities that provide free care on the Thai-Myanmar border to marginalized populations.  
126 Many women from Myanmar, which is a low-income country, must traverse difficult terrain in order to  
127 reach these ANCs. This includes traveling on dirt roads through forested mountainous areas that can be  
128 impassable in the rainy season, rivers, and border checkpoints. In the last two decades, deforestation and  
129 the establishment of year-round roads around health facilities (Figure 2) has increased the ease of travel  
130 and likely contributed to a decrease in malaria prevalence in the areas surrounding clinics.<sup>1</sup> Women  
131 attending SMRU ANCs from Thailand, which is an upper middle-income country, are predominantly  
132 undocumented, and though the roads are well maintained and SMRU provides subsidized transportation  
133 for women living far from ANC facilities there is some danger of being arrested or fined at a check-point  
134 on their way to receive care.<sup>16</sup>

135 Clinic records show that 17.4% of women who enrolled at the migrant ANCs stopped attending  
136 before giving birth and were lost to follow-up,<sup>2</sup> potentially indicating that there are barriers (i.e.  
137 geographic, socio-economic, or perceptions of antenatal services) preventing women from accessing care.  
138 A previous observational study in this population observed higher loss to follow-up in women with  
139 malaria infection, first pregnancy, and younger age of the mother.<sup>17</sup> A comprehensive analysis of factors  
140 influencing loss to follow-up and how those factors change from year to year has yet be completed. This  
141 manuscript investigates the relationship between travel distance and access to the full spectrum of  
142 pregnancy care. This work seeks to inform future public health interventions that address these problems,  
143 both locally and globally, where efforts to expand maternal healthcare access are ongoing.

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## 145 **DATA AND METHODS**

146 SMRU has been based on the Thai-Myanmar border for over 30 years. In response to an  
147 estimated maternal mortality in refugees of 1,000 per 100,000 live births in 1985-86, SMRU established a  
148 system of weekly ANCs to offer early detection and treatment of *Plasmodium falciparum* malaria in  
149 pregnancy.<sup>18</sup> As the population of migrant workers grew in the 1990's and 2000's, SMRU opened four  
150 facilities on the international border formed by the Moei River, which provided a mixture of antenatal  
151 care and skilled birth services. Mawker Thai (MKT) began providing ANC and skilled birth services in  
152 1998, Walley (WAL) and MuRu Chai (MRC) began providing ANC care in 2001, and Wang Pha (WPA)  
153 began providing ANC and skilled birth services in 2004. WAL closed operations in Jul 2010 and MRC in  
154 Dec 2012 and services were amalgamated at MKT. All services were free of charge<sup>19</sup> and attendance at  
155 ANCs was voluntary.

156 The maternal health facilities kept antenatal medical records for each pregnancy from 1986-2015  
157 which were de-identified and include general demographic information (patient age, gravidity, parity,  
158 home village name, and time lived at home village), antenatal care attendance information (estimated  
159 gestational age at initial presentation, miscarriages), pregnancy complication information (malaria  
160 infection with *P. vivax*, *P. falciparum*, or both, multiple pregnancy, very young age), and presence of  
161 skilled birth attendants at delivery (loss to follow-up and normal singleton delivery) (Figure 1).<sup>20</sup>

162 Loss to follow-up was defined as a women who enrolled at ANC but then stopped attending and  
163 did not return for delivery or postpartum care. Most women travel on foot to ANC appointments and a  
164 minority hire motorbikes or long-tractors for transportation. SMRU subsidizes transportation by car to  
165 prenatal visits for those who live on the Thai side of the border. All four facilities are built on the  
166 Thailand bank of Moei River and, depending on seasonal variations in rainwater, women use temporary  
167 bridges or boats to cross the river.

168 In 2014, SMRU worked to create and update a geographic information system (GIS) database for  
169 Kayin state, Myanmar and Tak province, Thailand. In Kayin State, SMRU travelled to remote villages by  
170 car, boat, or foot to obtain coordinates, which was the first systematic geographic study in the area since  
171 before World War II.<sup>21</sup> In Tak province, the Tak Malaria Initiative<sup>22</sup> had previously gathered village GPS  
172 coordinates, and SMRU performed an updated geographic survey in 2014. The Kayin and Tak GISs were  
173 used to link each unique pregnancy with GPS coordinates of their home village.

### 174 **Linking geospatial data to de-identified patient data**

175 The study team used geocoding to convert place names to map coordinates. They were blinded to  
176 all information in the patient record except village names, which they matched with coordinate data in the  
177 Kayin and Tak GISs. For the portion of villages not listed in GISs (n=105/1152), ANC clinic  
178 administrators with more than 20 years of experience pinpointed villages using Google Earth software.  
179 Patient addresses weren't consistently recorded at ANC clinics until late 2006 and the study team  
180 therefore limited this analysis to 2007 through 2015. All village names with unresolved locations were  
181 excluded from analysis, as were villages lying over 35km from the ANC given the possibility that these  
182 were mistaken village locations that did not represent actual patient experiences.

### 183 **Univariate analyses**

184 To understand travel distance to the facilities the straight-line (Euclidian) distance between each  
185 patient's village and the facility they attended were measured and used to calculate summary statistics and  
186 univariate analyses. The univariate analyses assessed whether travel distances differed across women  
187 based on year of childbirth, parity, age, malaria infection status, and pregnancy outcome. Travel distances  
188 across pregnancy outcomes (i.e. singleton delivery, twins, lost to follow-up, or miscarriage) was also  
189 compared. Miscarriage was defined as birth before 28 weeks gestational age based on published clinical  
190 experience of viability in this setting, where ventilatory support for newborns is not available.<sup>17</sup>

### 191 **Formal analysis: negative binomial regression**

195 Negative binomial regression was used to formally analyse potential predictors (i.e. covariates) of  
196 the straight-line distance travelled to a facility. Final predictor variables (covariates) in the models  
197 included: pregnancy outcome, maternal age in years, parity, year of childbirth, and years lived at the  
198 current village (Supplementary Table 1). A sensitivity analysis was conducted to attempt to account for  
199 potential error in geocoding (described in detail in Supplementary materials).

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#### 201 **Statistical software**

202 Maps were created using QGIS version 3.4.9. The Python programming language (version 3.6)  
203 was used to merge geocoded home villages to the patient records. R statistical software version 3.3.2 was  
204 used for all statistical analyses.

205

#### 206 **Role of the funding source**

207 The funding source (the Bill & Melinda Gates foundation) had no involvement in study design,  
208 collection, analysis, interpretation of data, writing, or the decision to submit the paper for publication

209

## 210 **RESULTS**

### 211 **Summary statistics and univariate analyses**

212 There were 17,522 unique pregnancy records with complete data from SMRU's four facilities for  
213 the study period of 2007-2015 identified. Successful linkage of 97.9% of these records (17,162/17,522) to  
214 GPS coordinates in the GIS databases was achieved. The remaining, unlinked records either did not list  
215 home villages, were recorded illegibly, or could not be located in the GIS databases and were excluded  
216 from analyses.

217 Figure 3 shows the estimated catchment areas for each of the four facilities across the study  
218 period (changes in catchment area over time are shown in Supplementary Figure 2). Women attending the  
219 WPA and MKT clinics travelled a longer distance to receive care compared to those attending WAL and  
220 MRC clinics. Median distance travelled increased over time as well (Table 1). At the beginning of the  
221 study period opened, most women were coming from nearby (Supplementary Table 4 and Supplementary  
222 Figure 2). Over time, women came from farther away, increases in travel distance are noted around June  
223 2010 when WAL patients were amalgamated to MKT, and in December 2012 when MRC patients were  
224 amalgamated to MKT. In 2007-2008 women travelled a median distance of less than 2km, but for 2011-  
225 2015 the median distance increased to over 7km (Table 1).

226 Travel distance was associated with maternal health service use across the spectrum of pregnancy  
227 care. Travel distance was negatively associated with number of antenatal visits (Supplementary Table 2).  
228 For antenatal care use, the 18% of women who began antenatal care in their third trimester also travelled  
229 a longer median distance compared to those who began in the first and second trimesters (Table 2).  
230 Women with miscarriages travelled farther distances compared to women with normal singleton  
231 deliveries (median 5.99km versus 5.24km) (Table 3). Women with pregnancy complications also  
232 travelled further compared to those without complications. Women with twins travelled longer median  
233 distances compared to women with singleton pregnancies (median 5.99km versus 5.24km) (Table 3), very  
234 young mothers (e.g. those aged 13-14) travelled a longer median distance for antenatal care compared to  
235 older mothers (Table 4), and women from Myanmar with *P. falciparum* malaria travelled further  
236 distances than those with *P. vivax* infections (Table 5, Supplementary Table 3). At the end of the  
237 pregnancy spectrum, women who were lost to follow-up and had no record of delivery in a facility with  
238 skilled birth services travelled 33% farther compared to women who had normal singleton deliveries in a  
239 skilled birth facility (median 6.96km versus 5.24km) (Table 3).

240

### 241 **Results from the negative binomial regression model**

242 Pregnant women who first presented for care in their third trimester came from 46% farther than  
243 those who first presented in their first trimester (DR: 1.46; CI: 1.39 – 1.53; from Table 6), and those with  
244 homes in Thailand travelled 63% farther than those with homes in Myanmar to receive care at ANCs  
245 (DR: 1.63; CI: 1.57- 1.69). Women with *P. falciparum* malaria came from 62% farther away (DR: 1.62;

246 CI: 1.44 – 1.82) than women who never had *P. falciparum* (Table 6), and those with *P. vivax* malaria  
247 travelled 23% farther than those without *P. vivax* (DR: 1.23; CI 1.15-1.32).

248 The regression also indicates that women lost to follow-up travelled 45% farther than women  
249 who had normal singleton deliveries (distance ratio (DR): 1.45; CI: 1.40 – 1.51) (Table 6). Women who  
250 eventually had a miscarriage travelled 23% farther than those who had normal singleton deliveries  
251 (distance ratio: 1.23; CI: 1.14 - 1.31).

252 Associations between pregnancy outcomes and travel distance were consistent in sensitivity  
253 analyses as well (Supplementary Table 3).

254

## 255 CONCLUSION

256 These results add to a growing body of literature, mainly gathered in low-income and resource-  
257 limited settings that highlight how travel distance limits access to care across the spectrum of pregnancy:  
258 from an absence of early antenatal care due to late presentation<sup>23</sup>, as a barrier to treatment in complicated  
259 pregnancies such as those with malaria,<sup>7,24</sup> and as a cause of lost to follow-up in childbirth.<sup>12,15,25</sup>

260 This analysis represents the first evidence that travel distance contributes to the high proportion of  
261 migrants who are lost to follow-up after enrolling in antenatal care on the Thai/Myanmar border. Given  
262 the paucity of any other antenatal care or delivery services for migrants in the rural Thai/Myanmar border  
263 region, it is likely that most of those lost to follow-up went without antenatal care and gave birth at home  
264 without a skilled attendant. Maternal and neonatal mortality are known to increase when women do not  
265 receive antenatal care<sup>3</sup> or deliver with skilled birth attendants, and although birth outcomes amongst  
266 women lost to follow-up was not available, they likely experience a higher risk of morbidity and mortality  
267 compared to those who attend ANC for care.<sup>26</sup>

268 This is the first evidence for geographic barriers to malaria care in pregnancy in this region,  
269 demonstrating that women with *P. falciparum*, and to a lesser extent *P. vivax* malaria, travel longer  
270 distances for antenatal care, which may contribute to the high rates of loss to follow-up in women with  
271 malaria, noted by Moore et al. 2016.<sup>17</sup> Stratified analysis suggests that this finding is restricted to those  
272 living on the Myanmar side of the border (Supplementary Table 4). Health facilities in Thailand have  
273 offered free antimalarials to anyone with a malaria diagnosis for decades, and SMRU has provided  
274 subsidized transportation to clinic by care for women living on the Thai side of the border. These  
275 differences by country of residence may be accounted for by both the decreased burden of *P. falciparum*  
276 malaria in Thailand after decades of concerted public health efforts as well as the increased access to care  
277 in Thailand provided by subsidized transportation to ANC. Since 2014 there has been a drastic increase in  
278 access to malaria diagnosis and treatment in Karen State as well.<sup>21</sup>

279 Treatment of malaria in pregnancy has been a major priority for preventing poor pregnancy  
280 outcomes worldwide, but the Thai/Myanmar border region faces unique challenges due to high rates of *P.*  
281 *falciparum* multi drug resistance<sup>27</sup> and the lack of a safe, radical cure that eliminates dormant *P. vivax*  
282 from the liver in pregnancy.<sup>28</sup> Recent initiatives have made progress by bringing curative *P. falciparum*  
283 treatments to rural villages<sup>21</sup>, but *P. vivax* now accounts for the majority of malaria infections in this  
284 region.<sup>28</sup> Since the current *P. vivax* treatments indicated in pregnancy only treat the blood stage of the  
285 infection, public health campaigns must focus on population-wide *P. vivax* screening and treatment of all  
286 non-pregnant residents, which is arguably the most effective tool to decrease the prevalence of *P. vivax*  
287 malaria in pregnancy in this region.<sup>2</sup>

288 This study also identified an association between longer distance travelled and late presentation  
289 for antenatal care, indicating limited access to mortality-reducing interventions amongst those living far  
290 from health facilities. Increased outreach services to enrol this population in ANC care during the first  
291 trimester will broaden access to folic acid supplements to prevent neural tube defects, iron supplements to  
292 treat anaemia, and HIV antivirals to prevent maternal-newborn transmission. That 59% of the study  
293 population (9761/16548; from Table 2) did not present until after the first trimester of pregnancy also  
294 suggests the need for clinical guidelines for antenatal care for those who miss their first trimester  
295 antenatal appointments.

296 Although these findings highlight poor access to care amongst those living far from ANC, they  
297 also demonstrate the remarkable resilience of women who overcome significant geographic barriers to  
298 attain healthcare. Facing high fevers from malaria and other complications of pregnancy, women often  
299 must travel long distances by foot to antenatal clinics and skilled birth services in the Thai-Myanmar  
300 border region.

301 These analyses and data are subject to several limitations. First, there are no officially numbered  
302 houses or named streets in the study area, and the addresses used in this analysis correspond to village  
303 names. The sensitivity analysis was geared toward testing for the reliability of the geocoding approach  
304 and the overarching consistency of the results, regardless of the catchment area used in the analysis,  
305 provides confidence in the validity of the results. The study population also includes women whose home  
306 location can change seasonally based on employment opportunities, and the addresses used only reflect  
307 where women lived at the time of their initial ANC visit. To control for this in the analysis a variable for  
308 the duration of time lived at the current address was included.

309 There are many women who were either too sick to travel, too far away, or without the social and  
310 financial resources to arrange for transportation to ANC. Data relied on clinic records and passive  
311 detection, leaving pregnant women who never came to a clinic or skilled birth facility unrepresented. This  
312 could introduce a selection bias for a healthier patient population, which is supported by studies that  
313 document an MMR of 250 (95% confidence interval of 150-430) amongst women attending antenatal  
314 care<sup>2</sup> and 721 in rural villages with limited ANC access (no confidence interval available).<sup>29</sup>

315 Finally, the model used Euclidian (straight-line) distance as a proxy for geographic access, which  
316 may not account for other geographic barriers to care such as the availability of roads, the presence of  
317 mountain ranges, rivers, and other geographic barriers, seasonal variations in rains that wash out dirt  
318 roads and bridges and make travel arduous or only possible when the water recedes. Travel distance and  
319 travel time have been found to closely correlate in other limited-resource settings, but no studies have  
320 examined whether that relationship holds in the Thai-Myanmar border region. The straight-line distance  
321 represents the easiest possible travel pathway, with reality being that travel is much more difficult.

322 Though there are limitations to this analysis, there are many strengths as well. It was possible to  
323 draw on an incredibly rich, longitudinal cohort of women followed across the spectrum of pregnancy,  
324 collected and maintained despite floods and armed conflicts. Although most studies on distance and  
325 access to maternal healthcare are survey-based or cross-sectional, this prospectively followed cohort  
326 follows women throughout the spectrum of maternity, from initial antenatal presentation up through  
327 delivery, and provides rich detail on the effect of geography on healthcare utilization throughout the  
328 entirety of pregnancy and across time. Further, until the expansion of malaria services into Kayin State in  
329 2014, such detailed geographic information was almost completely lacking. This analysis builds on the  
330 GIS established for the malaria elimination efforts in order to begin to understand the maternal and child  
331 health landscape of this region.

332 The results highlight a consistent problem in this region: poor access to healthcare contributing to  
333 loss to follow-up at ANCs in a region with persistently high maternal mortality. Empirical evidence is  
334 provided of geographic barriers to antenatal services for pregnant migrant women in Kayin state,  
335 Myanmar and Tak province, Thailand. To address these barriers, future ANCs could follow the model of  
336 SMRU's malaria elimination task force, which in 2014 trained a network of rural malaria post workers  
337 that substantially reduced the transmission of *P. falciparum* malaria.<sup>21</sup> Additionally, enhanced outreach  
338 services could be used to expand services outside of the walls of existing ANCs and into more rural, hard-  
339 to-reach villages. Regardless of the interventions selected, these findings speak to the need for both  
340 increased access to antenatal services as well as an enhanced public health surveillance system to  
341 proactively monitor health status and provide faster interventions to improve the accessibility of  
342 reproductive health care services. These findings can inform efforts to restructure healthcare on both the  
343 Thai/Myanmar border and in other settings where patients are lost to follow-up.

344 At least two further lines of research in this region are recommended. Quality of care may impact  
345 travel distances and has recently been shown to have a pronounced effect on decisions of where to seek  
346 care in other resource-limited settings.<sup>30</sup> A more nuanced analysis of distance including quality of care

347 measures would be important. Women in Thailand travelled 63% farther than women in Myanmar, but it  
348 remains unknown whether this was related to subsidized transport provided by SMRU, better roads and  
349 transportation infrastructure in Thailand, or other factors like availability of other ANC services.

350

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356

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358 None of the authors have any conflicts of interest to declare.

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454

**Table 1: Distance from home village to health facility by year of childbirth<sup>a</sup>**

year of childbirth	min	Q1	median	Q3	max	count
2007	0.00	0.89	1.97	5.47	33.82	1279
2008	0.00	0.89	1.97	6.58	33.82	1525
2009	0.00	0.89	2.17	6.96	30.98	1844
2010	0.00	0.89	4.72	8.06	30.62	1950
2011	0.00	0.89	6.27	8.70	33.82	1933
2012	0.00	0.89	6.41	9.35	30.98	1824
2013	0.00	2.17	6.96	12.87	31.27	2032
2014	0.00	3.93	7.52	15.20	31.27	2154
2015	0.00	2.17	7.52	15.44	33.82	2167

<sup>a</sup> WAL clinic closed in June 2010, and patients were amalgamated to MKT. MRC clinic closed in December 2012, and patients were amalgamated to MKT.

**Table 2: Distance from home village to health facility by trimester in which patient first presented for antenatal care**

Trimester of first attendance	min	Q1	median	Q3	max	count
first	0.00	0.89	4.72	7.52	33.82	6820
second	0.00	0.89	6.31	9.35	33.82	6919
third	0.00	1.97	7.10	15.44	33.82	2945

**Table 3: Distance from home village to health facility by pregnancy outcome**

Pregnancy Outcome	min	Q1	median	Q3	max	count
singleton delivery	0.00	0.89	5.24	8.05	33.82	10325
twins	0.00	1.10	5.99	10.50	30.62	125
miscarriage	0.00	0.89	5.99	8.73	33.82	1179
lost to follow-up	0.00	1.97	6.96	13.18	33.82	5079

**Table 4: Distance from home village to health facility by patient age**

Age Group (years)	min	Q1	median	Q3	max	count
13thr14	0.89	2.90	7.52	16.57	24.35	11
15thr19	0.00	1.10	5.99	9.35	33.82	2560
20thr24	0.00	0.89	5.99	9.35	33.82	4861
25thr29	0.00	0.89	5.99	9.04	33.82	3835
30thr34	0.00	0.89	5.99	8.87	33.82	2749
35thr39	0.00	0.89	5.47	8.33	33.82	1892
40plus	0.00	0.89	5.89	9.04	33.82	800

**Table 5: Distance from health facility by malaria status. Pf = *Plasmodium falciparum*, Pv = *Plasmodium vivax*.**

malaria status	min	Q1	median	Q3	max	count
no malaria	0.00	0.89	5.99	9.35	33.82	14305
Pf	0.00	1.10	5.99	8.87	33.82	891
Pv	0.00	0.89	4.73	7.43	30.98	1881
mixed	0.00	0.89	5.78	7.59	30.62	385

**Table 6: Results from a negative binomial regression for predictors of distance to the health facility.**  
The results are given as a ratio of the distances traveled (i.e. the distance ratio (DR)) between a variable and its comparison.

covariate	count	DR (95% CI)
<i>Pregnancy Outcome</i>		
normal singleton delivery	10325	
Lost to follow-up	5079	1.45 (1.40 - 1.51)
miscarriage	1179	1.23 (1.14 - 1.31)
twins delivery	125	1.16 (0.96 - 1.40)
<i>Trimester at first visit to ANC</i>		
1st trimester presentation	6787	
2nd trimester presentation	6843	1.21 (1.17 - 1.26)
3rd trimester presentation	2918	1.46 (1.39 - 1.53)
<i>Country of home village</i>		
Home village in Myanmar	8900	
Home village in Thailand	6669	1.63 (1.57 - 1.69)
<i>Malaria infections during pregnancy</i>		
no <i>P. falciparum</i> infection	15817	
<i>P. falciparum</i> infection	891	1.62 (1.44 - 1.82)
No <i>P. vivax</i>	14827	
<i>P. vivax</i> infection	1881	1.23 (1.15 - 1.32)
<i>Health facility where patient received care</i>		
MKT clinic	4487	
MLC clinic	1497	0.46 (0.41 - 0.50)
WAL clinic	771	0.38 (0.32 - 0.46)
WPA clinic	9953	1.03 (0.99 - 1.08)
<i>Patient age at initial ANC visit</i>		
Age 13 through 14	11	
Age 15 through 19	2560	0.81 (0.45 - 1.45)
Age 20 through 24	4861	0.80 (0.45 - 1.44)
Age 25 through 29	3835	0.78 (0.43 - 1.40)
Age 30 through 34	2749	0.77 (0.43 - 1.39)
Age 35 through 39	1892	0.69 (0.38 - 1.25)
Age 40 plus	800	0.71 (0.39 - 1.28)
<i>Patient birth date</i>		
year of birth		1.06 (1.05 - 1.07)
<i>Patient parity</i>		
Parity: 0	5803	

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Parity: 1	3729	0.97 (0.92 - 1.02)
Parity: 2-3	4552	1.00 (0.95 - 1.06)
Parity: 4-5	1930	1.09 (1.01 - 1.17)
Parity: 6 - 9	659	1.15 (1.03 - 1.28)
Parity: 10+	35	1.15 (0.78 - 1.69)
<i>Patient's years lived in their home village at time of initial ANC visit</i>		
Lived in home village for less than 1 year	4654	
Lived in home village for 1 through 3 years	2797	1.14 (1.09 - 1.19)
Lived in home village for 4 through 9 years	2524	0.97 (0.92 - 1.01)
Lived in home village for 10 or more years	1649	1.65 (1.57 - 1.74)

## FIGURES

### Figure 1: Outcomes across the pregnancy spectrum

**Figure 2:** Satellite images showing environmental changes over time for two of the antenatal clinics: Mawker Tai (top panel: A and B) and Wang Pha (bottom panel: C and D) clinics. The first columns (A for Mawker Tai and C for Wang Pha) show the larger geographic area whereas the second columns (B and D) show greater detail in the immediate clinic area (zoomed areas are indicated with the black boxes in A and C). The top rows show historical images and the bottom rows show more recent images. Deforestation is apparent, especially in the Mawker Tai images and on both the Thai and Myanmar side of the international border. Infrastructure and development has also increased at both clinics, with increased year-round roads, housing, and increased agricultural fields. Images come from Google Earth.

**Figure 3:** Map of the catchment areas for the four antenatal clinics (ANCs) from 2007-2015. Each of the four clinics is indicated by a different color scheme. The ellipses are standard deviational ellipses, with 2 and 3 standard deviations, explained in detail in the supplementary materials. The darker circle represents roughly 98% of women's home villages for that specific clinic and the lighter circle representing 99.9% of women's home villages. WPA (green) and MKT (blue) provided both antenatal care and skilled birth attendants, and MRC (yellow) and WAL (orange) provided antenatal care. WPA and MKT had the largest catchment areas whereas MLC and WAL served a more local population. Maps indicating changes in catchment area over time are presented in Supplementary Figure 2.

### Early pregnancy care

- Late attendance after the first trimester
- Miscarriage

### Complicated pregnancy

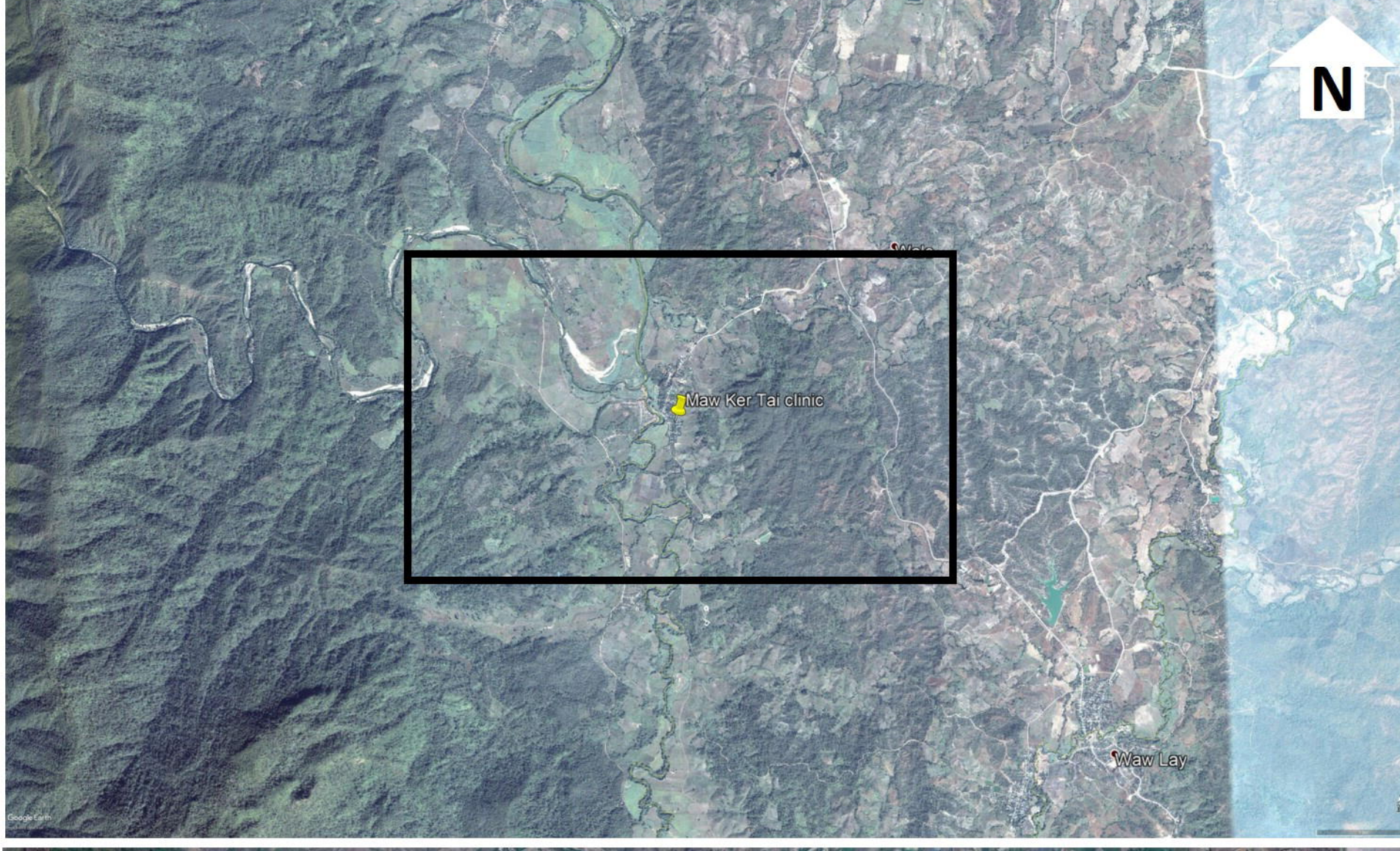
- Malaria
- Multiple pregnancy e.g. twins
- Very young teenagers (13, 14 years)

### Skilled attendance at birth

- Lost before child birth

February 2003

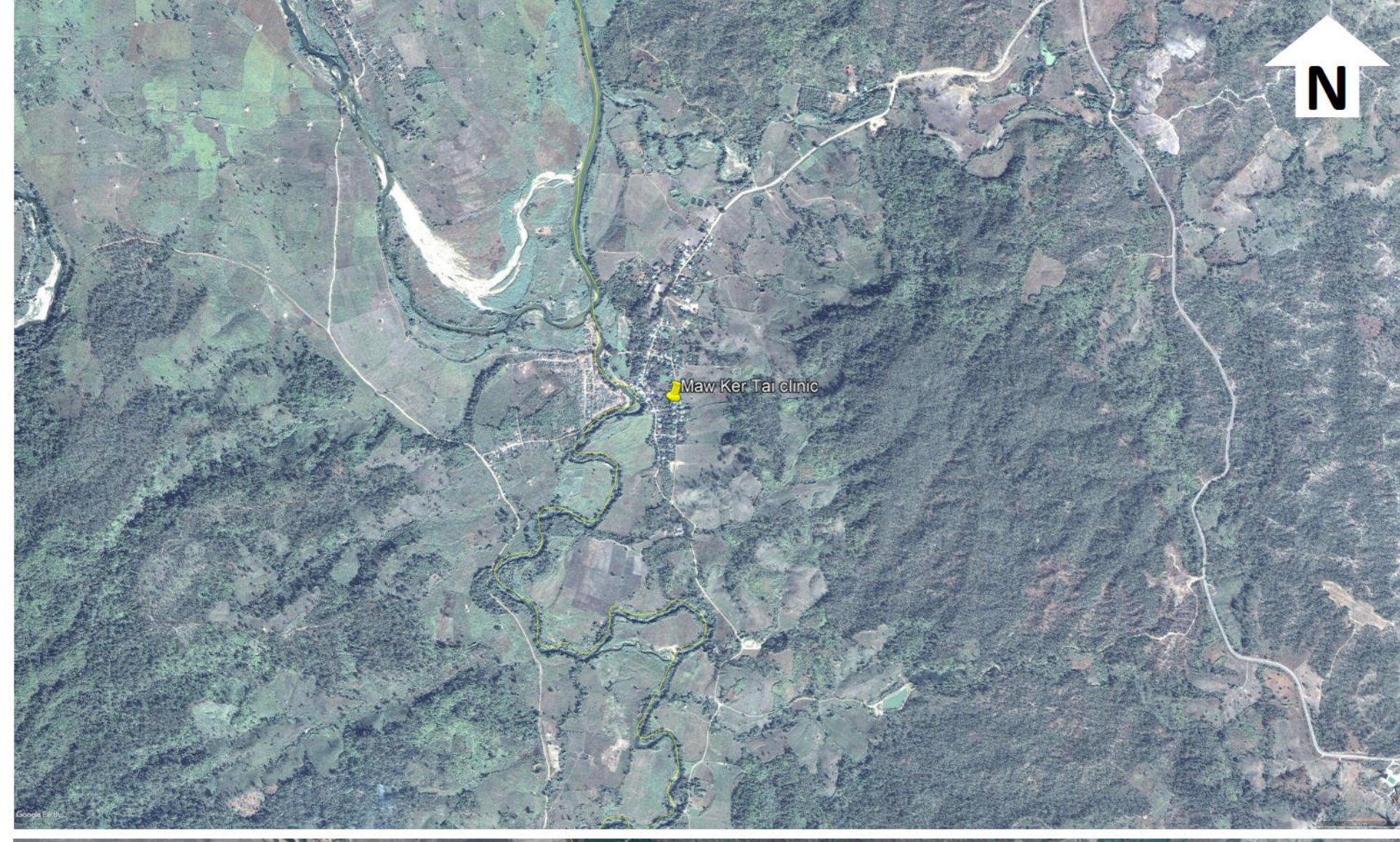
**A**



April 2016

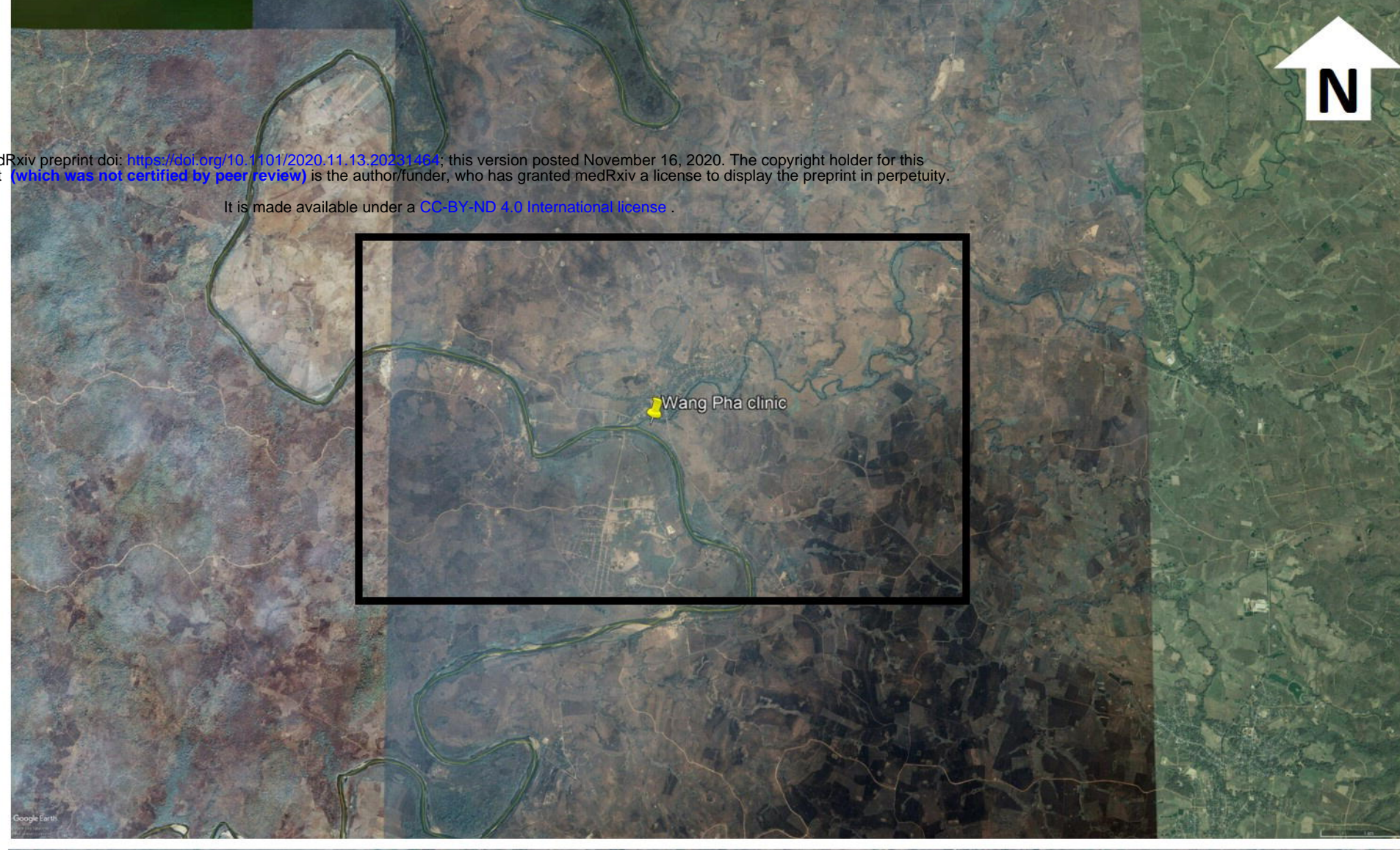


**B**

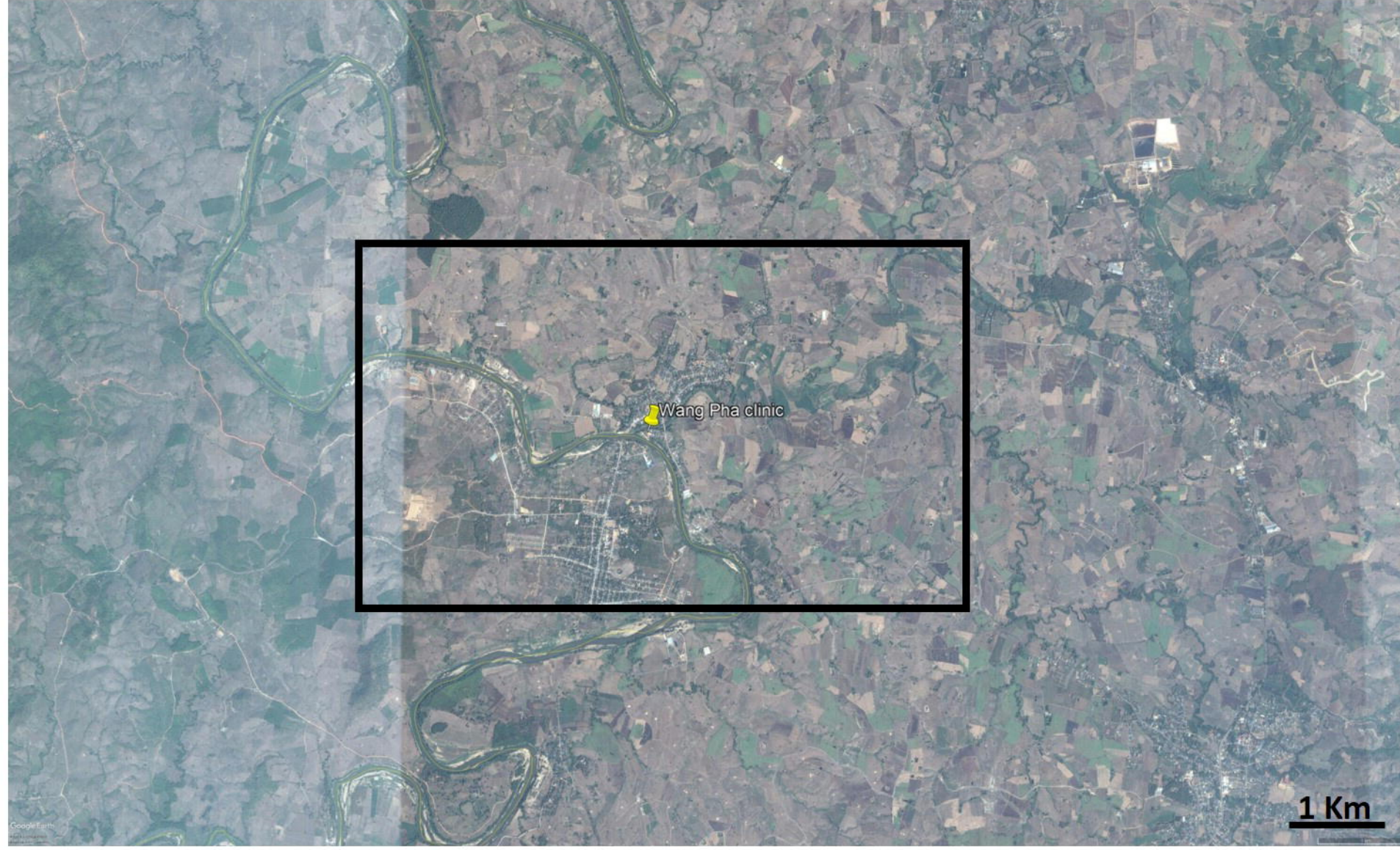


March 2002

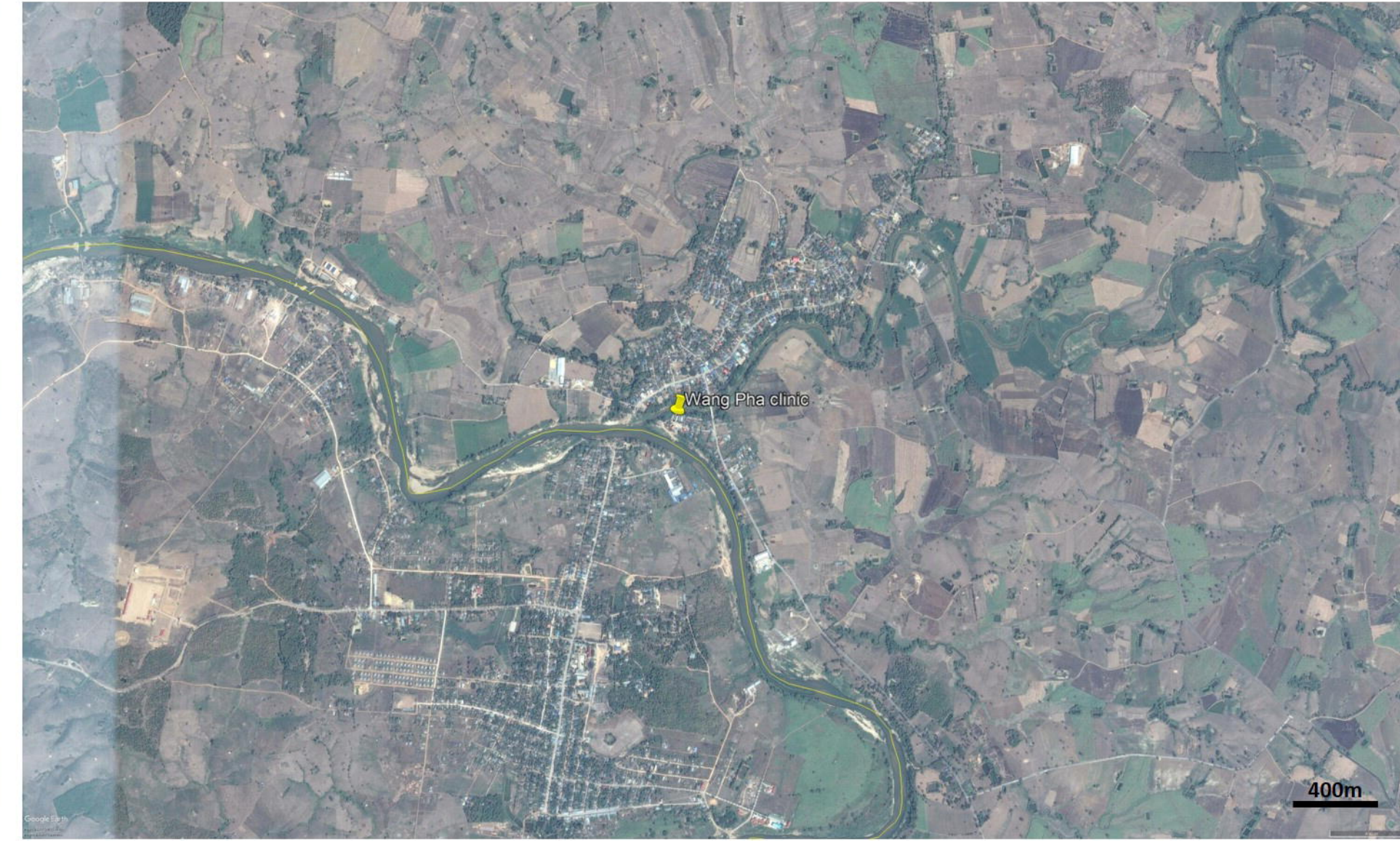
**C**



February 2016



**D**



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