Institute for Economic Studies, Keio University

Keio-IES Discussion Paper Series

The Quiet Lasting Impact of the Vietnam War on Children's Physical Development

Hiroyuki Yamada, TIEN MANH VU

23 July, 2025
DP2025-017
https://ies.keio.ac.jp/en/publications/26508/

Institute for Economic Studies, Keio University
2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan
ies-office@adst.keio.ac.jp

23 July, 2025

The Quiet Lasting Impact of the Vietnam War on Children's Physical Development

Hiroyuki Yamada, TIEN MANH VU
Keio-IES DP2025-017
23 July, 2025
JEL Classification: I15, N45, Z13
Keywords: Vietnam War, herbicide, children, physical development, health

Abstract

This paper examines the long-term health impacts of the large-scale herbicide spraying campaign by the U.S. in southern Vietnam during the Vietnam War on the height and weight of children under the age of 16 years in 2022, nearly 50 years after the Vietnam War ended. We combine the information on the age- and gender-adjusted z-score for the height and weight of children in 2022 with the herbicide spraying intensity at commune-level during the war. Our results using an instrumental variable approach show that communes that were exposed to greater amounts of herbicides during the war tended to have shorter children in 2022. Not only Agent Orange but also Agent White had a negative impact on children's height after half a century.

Hiroyuki Yamada
Keio University
hyamada@keio.jp

TIEN MANH VU
Chuo University
mvu264@g.chuo-u.ac.jp

Acknowledgement: This work was supported by JSPS (Japan Society for the Promotion of Science) KAKENHI Grant Numbers 25K05080 and Chuo University.

The Quiet Lasting Impact of the Vietnam War on Children's Physical Development

Hiroyuki Yamada* and Tien Manh Vu**

* (Corresponding author) Faculty of Economics, Keio University
2–15–45 Mita, Minato–ku, Tokyo 108–8345, Japan
Tel (Direct): +81-(0)3-5427-1271
E-mail: hyamada@keio.jp
https://orcid.org/0000-0003-3709-1914

** Faculty of Global Management, Chuo University
742-1 Higashinakano, Hachioji, Tokyo 192-0393, Japan
Email: mvu264@g.chuo-u.ac.jp
https://orcid.org/0000-0002-2251-0795

Acknowledgements: This work was supported by JSPS (Japan Society for the Promotion of Science) KAKENHI Grant Numbers 25K05080 and Chuo University.

Conflict of interest: The authors declare no conflicts of interest.

Abstract

This paper examines the long-term health impacts of the large-scale herbicide spraying campaign by the U.S. in southern Vietnam during the Vietnam War on the height and weight of children under the age of 16 years in 2022, nearly 50 years after the Vietnam War ended. We combine the information on the age- and gender-adjusted z-score for the height and weight of children in 2022 with the herbicide spraying intensity at commune-level during the war. Our results using an instrumental variable approach show that communes that were exposed to greater amounts of herbicides during the war tended to have shorter children in 2022. Not only Agent Orange but also Agent White had a negative impact on children's height after half a century.

Keywords: Vietnam War, herbicide, children, physical development, health
JEL Classification Codes: I15, N45, Z13

1. Introduction

April 30, 2025 marked the 50th anniversary of the end of the Vietnam War, a war that caused enormous human and environmental damage. According to historical estimates, between two and three million Vietnamese civilians and soldiers died over the course of the conflict, while the United States lost approximately 58,000 military personnel (Lewy, 1978; U.S. Department of Defense, 2005). Moreover, the chemical weapons sprayed by the U.S. military in southern Vietnam—particularly Agent Orange, which contained the dioxin compound TCDD—are said to have caused severe environmental pollution and serious negative health outcomes. Indeed, many public-health studies have reported the health impacts of the spray missions.[1] However, most were small sample studies, and studies using representative southern Vietnam samples are scarce.

This paper examines the long-term health impacts of the spray missions in southern Vietnam, using representative southern Vietnam survey data. Specifically, we focus on the height and weight of children under the age of 16 years in 2022, nearly 50 years after the Vietnam War ended. Combining the information on age- and gender-adjusted z-score for the height and weight of children in 2022 with herbicide spraying intensity at the commune level, we investigate whether the spray missions are associated with the physical development of the children in 2022. We apply an instrumental variable (IV) approach to infer the causal impacts of the spray missions.

Although the impacts of U.S. bombing missions have been extensively investigated using various data (Miguel and Roland 2011, Palmer et al. 2019, Singhal 2019, Appau et al. 2021, Vuong et al. 2021, Churchill et al. 2022), the literature on the health impacts of the U.S. spray missions remains relatively thin. Do (2009), Godpodinov and Nguyen (2015), and Le et al. (2022) concluded that herbicide exposure raises the risk of cancer, hypertension, and mobility disability, using the Vietnam National Health Survey for the outcome variables. Yamashita and Trinh (2022) and Vuong (2025) reported that individuals living in communes with greater exposure to herbicides are more likely to report disability issues, using the 2009 Population Census for the outcome variables.[2]

Built on earlier studies on the health impacts of the chemical weapons sprayed by the U.S. military in southern Vietnam, we aim to contribute to the literature in three ways. First, we use objective measures of health condition—height and weight—of children under the age of 16 years. These can be standardized using age- and gender-adjusted z-score for height and weight. In all the previously mentioned studies on the health impacts of U.S. spray missions, the outcome variables were self-reported health conditions. Although the objectively measured blood pressure was used to classify the respondents' hypertension status in Godpodinov and Nguyen (2015), the data on blood pressure were available for the respondents only, narrowing the scope of their analyses. Hence, our study is one of the first to use more objective measures of health condition in the context

[1] Among them are cancer risk (Schecter et al. 2001), birth defects (Ngo et al. 2006), cardiovascular disease mortality (Humblet et al. 2008), and skin diseases (Board on the Health of Select Populations, & Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides 2014)

[2] In addition to health dimensions, the impacts of the spray missions on agricultural productivity (Appau et al. 2021), educational outcomes (Bui and Imai 2024), and population size (Ito et al. 2023) have also been investigated.

of exploring the long-term health impacts of the chemicals.

Second, our study contributes to the literature on the impacts of armed conflicts on child health and development. Although there are some extensive review articles on these important issues (Kadir et al. 2019, Bendavid et al. 2021, Vesco et al. 2025), the literature on the long-term health impacts of armed conflicts on children is remains scarce. In particular, no previous studies have investigated the long-term health impacts of the chemicals. Hence, with many countries possessing chemical weapons today, our research could provide important evidence regarding the long-term effects of chemicals used in the war on children's health.

Third, earlier studies on U.S. spray missions in southern Vietnam focused mainly on Agent Orange. In our study, we utilize data on other types of herbicides, including Agent Blue and Agent White as well as Agent Orange, to investigate whether different types of herbicides might have different effects on children's physical development.

The remainder of this paper is organized as follows. Section 2 provides the background information and explains the country context of Vietnam. Section 3 explores the data. Section 4 shows the empirical model and estimation results. In Section 5, we discuss the obtained results and possible mechanisms. Finally, Section 6 presents the conclusions.

2. Background and context

The Vietnam War was a conflict situated within the broader context of ideological confrontation during the Cold War. It escalated into an international-scale war following the Gulf of Tonkin incident in 1964, which prompted full-scale military intervention by the United States (Herring, 2002). The war concluded with the fall of Saigon on April 30, 1975, leading to the reunification of Vietnam under the leadership of North Vietnam as a socialist state.

During the Vietnam War, the U.S. military conducted unprecedented bombing campaigns and deployed massive quantities of herbicides as part of its military strategy. From 1965 to 1973, the United States dropped an estimated 7.6 million tons of bombs on Vietnam, Laos, and Cambodia—more than three times the total tonnage used during World War II (Herring, 2002). The extensive bombing campaigns resulted in the destruction of urban centers, agricultural lands, and ecosystems, and caused the deaths of millions of civilians (Herring, 2002).

Simultaneously, the U.S. launched a large-scale herbicide-spraying program aimed at defoliating forests and destroying enemy crops. From 1961 to 1971, approximately 80 million liters of herbicide was sprayed over more than 24 thousand square kilometers of South Vietnam (Schecter et al., 2001), the most notorious of which was Agent Orange, a mixture of 2,4-D and 2,4,5-T. The latter compound was contaminated during production with TCDD, a highly toxic dioxin. TCDD is known to be carcinogenic, teratogenic, and immunotoxic, with long-lasting effects on both human health and the environment (Ngo et al., 2006). According to the Vietnamese Red Cross, more than three million people have experienced adverse health effects caused by Agent Orange, including more than 150,000 children born with severe birth defects (Fox, 2024).

While Agent Orange is the most infamous of the herbicides deployed by the U.S. military during the Vietnam War, it was only one of several chemical defoliants collectively referred to as the "Rainbow Herbicides." Among these, Agent Blue and Agent White were widely used for distinct tactical purposes and possessed different chemical compositions and toxicological profiles. Both played significant roles in shaping the environmental and health consequences of the war in Vietnam. Other types of herbicides include Agent Purple, Agent Pink, and Agent Green. According to the data we used for our analyses, the share of each herbicide in terms of volume was Agent Orange (60.94%), Agent Blue (6.51%), and Agent White (28.69%), followed by the other herbicides (remaining). Because the share of "other herbicides" is relatively small, we focus here on Agent Blue and Agent White in addition to Agent Orange.

Agent Blue was primarily employed for the destruction of agricultural crops, particularly rice fields. Its active ingredient was cacodylic acid, an organic arsenic compound. The herbicide was used heavily in agricultural zones, particularly in the Mekong Delta, with the aim of denying food sources to the Viet Cong and North Vietnamese Army (Young & Andrews, 2007). Although Agent Blue did not contain TCDD dioxin, it posed significant health and environmental risks due to its arsenic content. Chronic exposure to arsenic compounds has been associated with skin lesions, neurological disorders, and increased cancer risk (Westing, 1984). Moreover, due to its water solubility, cacodylic acid has been implicated in groundwater and soil contamination. An estimated 4 million liters of Agent Blue was sprayed during the war (Young & Andrews, 2007).

Agent White was introduced as a substitute for Agent Orange beginning in 1966, following growing concerns over the severe toxicity of 2,4,5-T and TCDD dioxin. Agent White was composed of 2,4-D (shared with Agent Orange) and picloram, a synthetic herbicide known for its long environmental persistence (Buckingham, 1982). Although Agent White contained no dioxin, picloram itself raised concerns due to its long half-life and high mobility in soil and water. It has been shown to remain in the environment for years, potentially impacting surrounding ecosystems (Westing, 1984). Approximately 20 million liters of Agent White was sprayed, mainly in the central regions of South Vietnam (Buckingham, 1982).

3. Data

Table 1 summarizes the variables used in this paper. Each variable is explained in order below.

3.1 Height and weight of children under 16 years old

The anthropometric data of children under the age of 16 years were obtained from the 2022 Vietnam Household Living Standards Survey (VHLSS 2022).[3] Specifically, these data are height (in centimeters with up to one decimal point) and weight (in kilograms with up to two decimal points). Information on whether the child stood up or lay down when their height was measured is available, as is the exact date of when the height and weight of each child was measured.

Using these data, together with WHO Child Growth Standards and WHO Growth

[3] VHLSS 2022 is a representative countrywide dataset obtained using a 2-stage stratified sampling method (3,133 enumeration areas based on the Population Census and Housing 2019). The VHLSS 2022 covers 46,995 households and about one third of the total communes in Vietnam. Every month in 2022, one twelfth of the households were surveyed (we calculate the age in months as of the month of the survey).

Reference 5–19 Years, we can determine the following indicators of physical growth in children: (1) height for age z-score of 0–16-year-olds (age in months, gender-adjusted) and (2) weight for age z-score of under 120 months of age (age in months, gender-adjusted).[4] In addition, we also compute the body mass index (BMI) for all children under the age of 16 years. [5] These indicators are used as the dependent variables in our analyses below.

3.2 Herbicide spray missions

The main variables of spray missions are aggregated at the administrative unit of commune. To compile commune-level data, we used the shapefile of commune-level administrative boundaries available at GADM maps and data, ver. 4.1 (https://gadm.org/index.html). Given that almost all the spray missions conducted were in Southern Vietnam, we focus the analysis on the impact of spray missions on the physical development of children in Southern Vietnam. That is, we extract the shapefile of communes in the southern Vietnam only. We have 1,612 communes in our final dataset for the estimations because the outcomes are from the VHLSS 2022, which are associated with about one third of the total communes in the country. For information on U.S. herbicide spray missions, we relied on the data obtained from AGENT ORANGE DATA WAREHOUSE (https://www.workerveteranhealth.org/milherbs/new/index.php), which is based on Stellman et al. (2003a,b) and Stellman and Stellman (2004). The website provides the information on the date, flight path, herbicide type, and volume (in gallons) of each spray mission. The dataset (last accessed June 11th, 2025) includes about 9,141 missions from 1961 to 1971, which sprayed a total of about 19 million gallons of defoliants. We acknowledge that the data on spray missions we use are incomplete. However, this is the most complete database so far on U.S. spray missions in Vietnam and has been used in the past studies.

In terms of the types of herbicides used, the most common was Agent Orange (60.94%), followed by Blue (6.51%), Pink (0.07%), Purple (2.54%), White (28.69%), and unknown. First, we calculated the total volume in liters (converted from gallon) for all types of herbicides spread across each commune. Then, we divide the aggregated volume of herbicides in liters in each commune by the area of the corresponding commune to get the volume of herbicides per area (liter/km^2) of each commune. Apart from this aggregated measure, we also calculated the volume of Agent Orange, Agent Blue, and Agent White per area (liter/km^2) in each commune to see whether different sprays have different impacts on the physical development of children

3.3 Distance from communes to the nearest the North Vietnamese Army base

Following Le et al. (2022), we use the distance in kilometers from the communes to the nearest the North Vietnamese Army (NVA) base as the instrumental variable for

---

[4] The WHO Child Growth Standards and WHO Growth Reference 5–19 Years can be found at https://www.who.int/tools/child-growth-standards and https://www.who.int/tools/growth-reference-data-for-5to19-years, respectively.

[5] The BMI for the age-adjusted z-score for <60 months of age (age in months) was also obtained using the WHO Child Growth Standards, but we do not use this variable because of the small sample size.

the intensity of spray missions in the commune. Increased herbicide exposure in the past constitutes the sole mechanism through which proximity to NVA bases during the war might have impacted child development in recent years. This appears to be a reasonable assumption, considering that NVA primarily relied on guerrilla warfare tactics characterized by the unpredictability of their movements.

The locations of NVA's bases from July 1 in 1966 to November 8 in 1971 were obtained from the Enemy Base Area Files (BASFA) database created by the U.S. Department of Defense (https://catalog.archives.gov/id/600139). We regard the distance from the geographical centroid of the commune to the nearest NVA base as an instrumental variable. Here also, we focus the analysis on the impact of spray missions on the physical development of children in southern Vietnam because almost all the spray missions were conducted in southern Vietnam.

3.4 Control variables

As a set of individual-level control variables, we include age in months, gender dummy (=1 if female, 0 otherwise), the number of household members (in log), living space (in log), whether an individual has a health insurance or not (=1 if yes, 0 otherwise), and whether an individual is entitled to a monthly social protection allowance for persons with disabilities or not (=1 if yes, 0 otherwise). For the case of height, a dummy on whether height was measured standing upright or lying down (=1 if lying down, 0 otherwise) is included as well.

At the commune level, we include the following two variables. First, we include commune-level information on U.S. bombing missions. We referred to the Theater History of Operations Reports (THOR) dataset, which is publicly available from the U.S. Department of Defense. THOR is a reliable source for reviewing U.S. air activity from 1915 to 1975. This dataset contains mission-level data for all Vietnam War bombing missions, including who (callsign, service, country), how many (strikes, weapons, etc.), what kind (aircraft, weapons, etc.), when, and, importantly, where (i.e., geographical coordinates). The oldest available data are from 1965 and the most recent are from 1973. We aggregate the weight of bombs (in tons) dropped in each commune from 1965 to 1973. Then, we divide the aggregated weight of bombs in each commune by the area of the corresponding commune to get the weight in tons of bombs per area (km^2) of each commune. This variable is the degree of bombing intensity in the commune.

Second, we include average elevation in meters of the commune, which is calculated using the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global data obtained from the U.S. Geological Survey (https://earthexplorer.usgs.gov).

4. Empirical model and estimation results

4.1 Empirical model

To estimate the impact of herbicide spray missions on the physical development of children after about 50 years, we apply a standard linear regression specification with district fixed effects. The sample unit is individual children. Specifically, we estimate the following empirical model:

$$Outcome_{ic} = \delta_0 + \delta_1 lnSpray_c + control'_{ic}\delta_2 + \theta_d + \epsilon_{ic}, (1)$$

where $Outcome_{ic}$ is one of the outcome variables of individual i in commune c, which is explained in the previous section. $lnSpray_c$ is the volume of herbicides per area (liter/km^2) sprayed in commune c. We use an inverse hyperbolic sine transformation similar to logarithm transformation, which allows zero-valued observations to be retained.[6] This is our main variable of interest. $control_{ic}$ is a vector of individual- and commune-level control variables for individual i in commune c. This vector includes commune-level bombing intensity and average elevation as well. θ_d is a district fixed effect and ϵ_{ic} is the error term. Note that in this analysis, we use the sample of individuals in southern Vietnam.

The locations where herbicides were sprayed were probably not random. This is because the U.S. troop's strategy was aimed mainly at defoliating forests and destroying food sources, with the goal of exposing and harassing North Vietnamese guerrilla forces. Therefore, it is likely that most of these operations were concentrated in areas identified by U.S. intelligence agencies as infiltration points from the north. Hence, a simple estimation of (1) using ordinary least squares (OLS) may yield biased estimates.

To overcome this endogeneity concern, we apply an IV approach. The IV is the distance from the geographical centroid of the (present-day) commune to the nearest NVA base, as explained in the previous section. Figure 1 shows the locations of NVA bases (yellow dots) and herbicide targets (green dots) superimposed on a map of commune boundaries. The herbicide targets are very close to or overlapped with the locations of NVA bases, implying the distance from the geographical centroid of the commune to the nearest NVA base could be a potential IV. In addition, our IV approach is valid under the assumption that proximity to NVA bases during the war affected the physical development of children in Southern Vietnam after about 50 years only through increased past herbicide exposure. This assumption is justifiable, given that North Vietnamese forces predominantly relied on guerrilla warfare tactics, characterized by the unpredictability of their movements (Le et al., 2022).

Specifically, D_Base_c is the distance from the geographical centroid of commune c to the nearest NVA base. Using this IV, we estimate the following first stage equation:

$$lnSpray_c = \pi_0 + \pi_1 D\_Base_c + \pi_2 control'_{ic} + \vartheta_c + \rho_{ic}, \quad (2)$$

where ϑ_c is a district fixed effect and ρ_{ic} is the error term. Note that NVA bases are scattered throughout South Vietnam and near the country's border with Laos and Cambodia (Truong Son trail or Ho Chi Minh trail), and the distance from the nearest NVA base varies even between communes within the same district. Therefore, by including district fixed effects, we intend to use the variation in the distance from the nearest NVA base between communes within the same district. This is a new approach that has not been used in previous studies. We estimate the second-stage specification (1) in which $lnSpray_c$ is replaced with the fitted value from (2). Standard errors are clustered at the district level.

---

[6] The inverse hyperbolic sine transformation of x is denoted by the following equation: $ln\left(x + \sqrt{x^2 + 1}\right)$.

For the estimations, we restrict the sample to individuals whose z-scores fall within five standard deviations of the sample mean (−0.710 for height-for-age and 0.075 for weight-for-age). Assuming a standard normal distribution, 99.99% of observations lie within this range. Although the WHO Child Growth Standards and the WHO Growth Reference for the ages 5–19 years allow for values up to six standard deviations from the mean of zero, we adopt a more conservative threshold to minimize the influence of outliers. Furthermore, accurately measuring infants' physical characteristics can be challenging for enumerators, and there is a high likelihood of measurement errors. Therefore, we also conducted estimations using a sample restricted to children aged 13 months and older. For BMI, the sample is restricted to individuals whose z-scores fall within five standard deviations of the sample mean for height-for-age, and further limited to those aged 13 months or older.

4.2 Estimation results

Table 2 shows the estimation results for height. Our preferable specification is the one that includes the control variables and district fixed effects. Hence, the results shown in Table 2 include them. Columns (1) and (2) show the IV estimation results using the aggregated volume of all types of herbicides per area (liter/km^2). In Column (1), we use the sample of individuals whose z-score is within five standard deviations from the sample mean. The coefficient of $lnSpray$ is negative, implying children currently residing in communes that were more heavily sprayed with herbicides per square kilometer during the Vietnam War tend to be shorter, but the result is not statistically significant. In Column (2), we further restrict the sample to individuals whose z-scores fall within five standard deviations of the sample mean for height-for-age, and further limited to those aged 13 months or older. The coefficient of $lnSpray$ is negative and statistically significant at the 10% level. Using the point estimate, this implies that one standard deviation increase in $lnSpray$ leads to a 0.0861 lower z-score in height-for-age, holding other factors constant. For instance, this magnitude can be interpreted as follows. From the WHO Growth Reference 5–19 Years, we know that the median height of boys aged 120 months (i.e., exactly 10 years) is 137.77 cm. A 0.0861 lower z-score implies a height of 137.27 cm, about 0.5 cm lower than the median. The IV is strong enough at the first stages, looking at the value of F-statistics (about 20), rejecting the concern of a weak IV.

Although our main analysis aggregates the volume of all herbicides to examine the overall impact of spray missions, we also present the herbicide-specific effects in Columns (3)–(8). Specifically, we investigate the impacts of Agent Orange (Columns (3) and (4)), Agent Blue (Columns (5) and (6)), and Agent White (Columns (7) and (8)) on children's height. However, the results for Agent Blue in Columns (5) and (6) suffer from small F-values in the first stage. Therefore, we were unable to obtain reliable results for Agent Blue.

The qualitative results for Agent Orange and Agent White are similar to those for the aggregated volume of all types of herbicides in Column (1) and (2). When using the sample of individuals whose z-score is within five standard deviations from the mean, the coefficients for Agent Orange and Agent White are negative but statistically insignificant. However, when restricting the sample to individuals whose z-scores fall within five standard deviations of the sample mean for height-for-age, and further limited to those aged 13 months or older, the coefficients for Agent Orange and Agent White are negative and statistically significant at the 10% level. That is, children currently residing in communes that were more heavily sprayed with Agent Orange and Agent White (liter/km^2) during the Vietnam War tend to be shorter. Using the point estimates, one standard deviation increase in Agent Orange and Agent White leads to 0.2392 and 0.2925 lower gender-adjusted z-scores in height-for-age, respectively, holding other factors constant. These magnitudes imply, for instance, that the height of boys aged 120 months is respectively 1.49 and 1.81 cm lower than the median height. Looking at the values of the F-statistics at the first stage, the IV is strong enough for the case of Agent Orange but not for that of Agent White, implying the need for caution in interpreting the results.

In sum, these results indicate that the herbicide spray missions during the Vietnam War—particularly those involving Agent Orange and Agent White—might have exerted a long-term negative effect on children's height nearly half a century later.

Table 3 shows the estimation results for the weight of children under the age of 120 months. All empirical specifications include the control variables and district fixed effects, and the IV method is applied. In all cases, the coefficients of spray missions are insignificant. In addition, the IV is weak in the case of Agent Blue (Columns (5) and (6)). Thus, there is no clear impact of the spray missions during the Vietnam War on the weight of children after about 50 years.

Finally, Table 4 show the impact of spray missions on BMI. We use an IV approach with the control variables and district fixed effects in all Columns. All columns show a *positive* impact of spray missions on BMI. This positive impact of spray missions on BMI is a natural consequence of the negative impact of spray missions on gender-adjusted height-for-age. However, the IV is weak for Agent Blue (Columns (5) and (6)) and not very strong for Agent White (Columns (7) and (8)). Indeed, the first-stage results are identical to those in Table 2 because the same sample was used. Therefore, children living in communes where more herbicides—particularly Agent Orange and Agent White—were dropped tend to be shorter in height compared with other children, even though their weight is comparable, suggesting that they may be in poor health.

5. Discussion and possible mechanisms

Several previous studies investigated the impact of spray missions, particularly Agent Orange, on health. All of them used self-reported health conditions, including self-reported disability (Le et al., 2022, Yamashita and Trinh 2022, Vuong 2025) and self-reported and proxy-reported cancer status and blood pressure disease (Do 2009, Godpodinov and Nguyen 2015, Le et al. 2022).[7, 8] One exception is Vuong et al. (2021), which used height and weight, which are very objective measures of health, although they restricted the sample to cohorts born between 1960 and 1975.[9] In addition, while they

---

[7] Godpodinov and Nguyen (2015) used only the objectively measured blood pressure of survey respondents to classify their hypertension status, which is quite different from the representative value for south Vietnam.

[8] Other studies in the field of public health literature have investigated the health impacts of Agent Orange on cardiovascular disease mortality (Humblet et al. 2008) and skin diseases (Board on the Health of Select Populations, & Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides 2014), but they used small sample sizes not representative of southern Vietnam.

[9] Since Vuong et al. (2021) used information on height and weight collected in the 2002 Vietnam

found a negative impact of U.S. *bombing* on height and weight in southern Vietnam among the cohorts, they rejected the possibility that these results were due to Agent Orange. Our study uses the sample of children under the age of 16 years in 2022, nearly 50 years after the end of the Vietnam War, to ascertain the negative impacts of the spray missions, including not only Agent Orange but also Agent White, on children's height. However, caution is warranted in interpreting the results for the case of Agent White because the first-stage result is not very strong. Height is a very objective health measure and the finding is indeed a new insight.

As for the mechanisms, there are several potential channels, but it is highly challenging or nearly impossible to determine which is the most plausible. First, there could be a biological channel. That is, spray missions harmed the former generations' height, and that harmful impact was genetically transmitted to children under 16 years old in 2022. However, to our knowledge, there is currently no clear direct research indicating that exposure to spray missions during the Vietnam War resulted in shorter stature. This directly implies that no previous research has demonstrated the intergenerational transmission of reduced height caused by the spray missions. For instance, Giuliani et al. (2018) reported that the offspring of Vietnamese parents exposed to Agent Orange shared a distinctive CYP1A1 DNA methylation signature that was not seen in the children of parents with no exposure. However, they note that their study does not experimentally demonstrate that exposure to dioxin is transmitted to descendants, nor does it address the question of whether any changes are harmful, beneficial, or neutral.[10]

Second, the spray mission posed a harmful impact on the affected lands, which has led to lower agricultural productivity. This lower agricultural productivity might induce malnutrition in affected areas even today. Indeed, previous studies have pointed out that dioxin TCDD can remain in the soil for decades (Mai et al. 2007, Huyen et al. 2015, Olson and Morton 2019). Under such conditions, the land area suitable for cultivation might continue to be limited. In addition, Appau et al. (2021) reported that an increase in Agent Orange intensity correlates with decreased rice and total agricultural productivity. Thus, food shortages may be persistent in the affected areas for many years, which could result in malnutrition. This channel could explain the shorter stature.

Third, some studies have reported that older generations might have transmitted the impact of dioxin exposure to younger generations due to their worsening health and socioeconomic conditions (Vuong 2025). For instance, people located in a commune with greater exposure to herbicides during the war were more likely to suffer from a health disease medically linked to spray missions three decades later (Le et al. 2022). This worsened health condition was directly related to the worsened socioeconomic conditions of those affected. If their children were subjected to harsh living conditions including poor nutrition status, it might have led to shorter stature, even in 2022.

Although the possible mechanisms discussed above are plausible, we cannot say which is the most plausible. Moreover, there might be other mechanisms that could explain our findings. Hence, we acknowledge that more research is needed to identify the true mechanisms.

National Health Survey, no adjustment of height and weight for age was possible because all the individuals in their sample were already adults in 2002.

[10] Normile (2025) reported that researchers still struggle to document the long-term health effects of the massive spraying of Agent Orange and other herbicides nearly 50 years after the end of the Vietnam War.

6. Conclusions

Despite the fact that the use of chemical weapons such as herbicide causes serious negative health outcomes, there is currently a lack of large-scale-data–based research on their long-term effects, particularly for future generations. Considering these circumstances, this study examined the impact of herbicides sprayed by the U.S. military in southern Vietnam during the Vietnam War on the physical development of children approximately 50 years after the end of the war. We found that children in the communes with greater exposure to herbicides during the Vietnam War tend to be shorter in 2022. This is the first evidence of the negative long-term health impacts of herbicides on children in the later generations, using large-scale microdata.

We have presented several plausible mechanisms to explain our results, but we are still far from elucidating the definitive mechanism, and further research is needed. In addition, similar to all previous studies on the impacts of U.S. spray missions in southern Vietnam, migration is a crucial threat to our identification strategy. However, we sincerely hope that this study will serve as a deterrent against the future use of chemical weapons such as herbicides.

References

Appau, S., Churchill, S. A., Smyth, R., & Trinh, T. A. (2021). The long-term impact of the Vietnam War on agricultural productivity. *World Development*, *146*, 105613.

Bendavid, E., Boerma, T., Akseer, N., Langer, A., Malembaka, E. B., Okiro, E. A., ... & Wise, P. (2021). The effects of armed conflict on the health of women and children. *The Lancet*, *397*(10273), 522-532.

Board on the Health of Select Populations, & Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides (Ninth Biennial Update). (2014). *Veterans and Agent Orange: Update 2012*. National Academies Press.Veterans and agent orange: Update 2002.

Buckingham, W. A. Jr. (1982). *Operation Ranch Hand: The Air Force and herbicides in Southeast Asia, 1961–1971*. Office of Air Force History.

Bui, T., & Imai, K. S. (2024). *Are There Any Long-lasting Human-Capital Effects from Exposure to the United States' Herbicide Bombings Over Generations?: Evidence from the Vietnam War*. School of Social Sciences, The University of Manchester.

Churchill, S. A., Smyth, R., & Trinh, T. A. (2022). The intergenerational impacts of War: Bombings and child labour in Vietnam. *The Journal of Development Studies*, *58*(11), 2290-2306.

Do, Q. T. (2009). Agent orange and the prevalence of cancer among the Vietnamese population 30 years after the end of the Vietnam war. *World Bank Policy Research Working Paper*, (5041).

Fox, D. N. (2024). *Living with Agent Orange: Conversations in postwar Việt Nam*. University of Massachusetts Press.

Giuliani, C., Biggs, D., Nguyen, T. T., Marasco, E., De Fanti, S., Garagnani, P., ... & Romeo, G. (2018). First evidence of association between past environmental exposure to dioxin and DNA methylation of CYP1A1 and IGF2 genes in present day Vietnamese population. *Environmental Pollution*, *242*, 976-985.

Godpodinov, N., & Nguyen, H. V. (2015). Long-term health effects of Vietnam War's herbicide exposure on the Vietnamese population. *Canadian Centre for Health Economics Working Paper Series*, *150019*.

Herring, G. C. (2002). America's longest war: The United States and Vietnam, 1950–1975 (4th ed.). McGraw-Hill.

Humblet, O., Birnbaum, L., Rimm, E., Mittleman, M. A., & Hauser, R. (2008). Dioxins and cardiovascular disease mortality. *Environmental health* *perspectives*, *116*(11), 1443-1448.

Huyen, D. T., Igarashi, T., & Shiraiwa, T. (2015). Vertical distribution of dioxins in soil of Bien Hoa airbase, Vietnam. *SpringerPlus*, 4(1), 300.

Ito, G., Tran, D., & Yoshida, Y. (2023). Not Gone with the Wind: Long-Run Impact of Herbicidal Warfare in Vietnam. Available at SSRN 4512129.

Kadir, A., Shenoda, S., & Goldhagen, J. (2019). Effects of armed conflict on child health and development: a systematic review. *PloS one*, *14*(1), e0210071.

Le, D. T., Pham, T. M., & Polachek, S. (2022). The long-term health impact of Agent Orange: Evidence from the Vietnam War. *World Development*, *155*, 105813.

Lewy, G. (1978). *America in Vietnam*. Oxford University Press.

Mai, T. A., Doan, T. V., Tarradellas, J., de Alencastro, L. F., & Grandjean, D. (2007). Dioxin contamination in soils of Southern Vietnam. *Chemosphere*, 67(9), 1802-1807.

Miguel, E., & Roland, G. (2011). The long-run impact of bombing Vietnam. *Journal of Development Economics*, *96*(1), 1-15.

Ngo, A. D., Taylor, R., Roberts, C. L., & Nguyen, T. V. (2006). Association between Agent Orange and birth defects: Systematic review and meta-analysis. *International Journal of Epidemiology*, 35(5), 1220–1230.

Normile, D. (2025). The fog of war. *Science (New York, NY)*, *388*(6745), 350-353.

Olson, K. R., & Morton, L. W. (2019). Long-term fate of Agent Orange and dioxin TCDD contaminated soils and sediments in Vietnam hotspots. *Open Journal of Soil Science*, 9(01), 1.

Palmer, M., Nguyen, C. V., Mitra, S., Mont, D., & Groce, N. E. (2019). Long-lasting consequences of war on disability. *Journal of Peace Research*, *56*(6), 860-875.

Schecter, A., Le Cao Dai, Päpke, O., Prange, J., & Constable, J. D. (2001). Recent dioxin contamination from Agent Orange in residents of a southern Vietnam city. Journal of Occupational and Environmental Medicine, 43(5), 435–443.

Singhal, S. (2019). Early life shocks and mental health: The long-term effect of war in Vietnam. *Journal of Development Economics*, *141*, 102244.

Stellman, S. D., & Stellman, J. M. (2004). Exposure opportunity models for Agent Orange, dioxin, and other military herbicides used in Vietnam, 1961–1971. *Journal of Exposure Science & Environmental Epidemiology*, *14*(4), 354-362.

Stellman, J. M., Stellman, S. D., Christian, R., Weber, T., & Tomasallo, C. (2003a). The extent and patterns of usage of Agent Orange and other herbicides in Vietnam. *Nature*, *422*(6933), 681-687.

Stellman, J. M., Stellman, S. D., Weber, T., Tomasallo, C., Stellman, A. B., & Christian Jr, R. (2003b). A geographic information system for characterizing exposure to Agent Orange and other herbicides in Vietnam. *Environmental Health Perspectives*, *111*(3), 321-328.

U.S. Department of Defense. (2005). *Statistical information about casualties of the Vietnam War*.

Vesco, P., Baliki, G., Brück, T., Döring, S., Eriksson, A., Fjelde, H., ... & Hegre, H. (2025). The impacts of armed conflict on human development: A review of the literature. *World Development*, *187*, 106806.

Vuong, N. D. T. (2025). The Persistent Health Effects of Defoliating Vietnam. *Mimeograph*.

Vuong, V., Chang, S., & Palmer, M. (2021). Bombing and the Two Vietnams.

Westing, A. H. (1984). *Herbicides in War: The Long-term Ecological and Human Consequences*. Taylor & Francis.

Yamashita, N., & Trinh, T. A. (2022). Long-Term Effects of Vietnam War: Agent Orange and the Health of Vietnamese People After 30 Years. *Asian Economic Journal*, *36*(2), 180-202.

Young, A. L., & Andrews, W. B. (2007). *The History, Use, Disposition and Environmental Fate of Agent Orange*. Springer.

Figure 1:
Locations of North Vietnamese Army (NVA) bases (yellow dots) and herbicide targets (green dots) superimposed on a map of commune boundaries in southern Vietnam

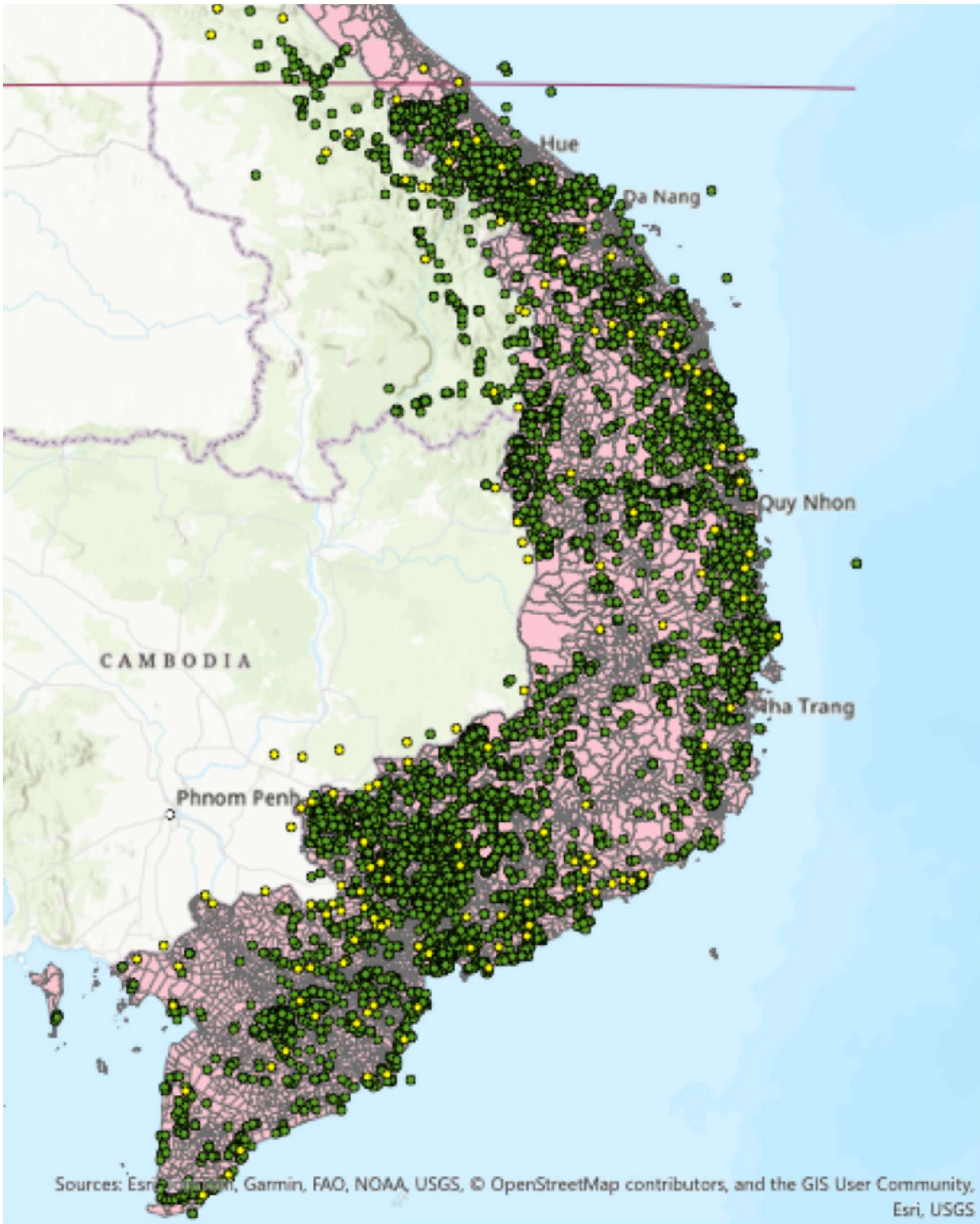

Table 1: Descriptive statistics

	Obs	Mean	St. Dev.
Outcome variables			
Height-for-age (z-score: under 16 years of age))	20,668	−0.710	1.666
Weight-for-age (z-score: under 160 months of age)	12,080	0.075	1.484
Body Mass Index (BMI: under 16 years of age)	20,668	18.063	3.568
Main variables of interest (Liter per squared kilometer)			
ln (volume of all types of herbicides per area): *lnSpray*	20,668	−0.616	4.553
ln (volume of Agent Orange per area): *lnAgent Orange*	20,668	−1.760	3.441
ln (volume of Agent Blue per area): *lnAgent Blue*	20,668	−2.908	1.989
ln (volume of Agent White per area): *lnAgent White*	20,668	−2.311	2.893
Instrumental Variable (Kilometer)			
Distance to the nearest the North Vietnamese Army (NVA) base	20,668	19.552	11.964
Control variables: Individual level			
Age in months	20,668	104.552	51.754
Gender (=1 if female, 0 otherwise)	20,668	0.483	0.500
ln(the number of household members)	20,668	1.546	0.297
ln(living space)	20,668	4.416	0.558
Has health insurance? (=1 if yes, 0 otherwise)	20,668	0.963	0.187
Entitled to social protection beneficiaries for disability? (=1 if yes, no otherwise)	20,668	0.004	0.062
Height was measured lying down? (=1 if yes, 0 otherwise)	20,668	0.031	0.173
Control variables: commune level			
Weight of bombs per area (ton/km^2)	20,668	0.040	0.084
Average elevation (meter)	20,668	147.592	279.838

Table 2: Impacts of spray missions on height

Dependent variable	Z-score of height-for-age							
Sample selection criteria 1	Within 5 standard deviations from the mean							
Sample selection criteria 2	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation method	IV	IV	IV	IV	IV	IV	IV	IV
Panel A: Second-stage results								
lnSpray	−0.0464	−0.0517*						
	(0.0292)	(0.0289)						
lnAgent Orange			−0.0619	−0.0695*				
			(0.0380)	(0.0378)				
lnAgent Blue					−0.1871	−0.2073		
					(0.1314)	(0.1316)		
lnAgent White							−0.0907	−0.1011*
							(0.0600)	(0.0601)
Panel B: First-stage results								
D_Base	−0.1296***	−0.1310***	−0.0971***	−0.0974***	−0.0321***	−0.0326***	−0.0662***	−0.0669***
	(0.0292)	(0.0292)	(0.0246)	(0.0247)	(0.0117)	(0.0119)	(0.0200)	(0.0200)
F test of excluded instrument	19.72	20.08	15.54	15.56	7.44	7.48	10.97	11.20
R-squared of the first stage	0.0302	0.0307	0.0290	0.0289	0.0127	0.0132	0.0259	0.0263
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,502	19,820	20,502	19,820	20,502	19,820	20,502	19,820

Standard errors clustered at district level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Impacts of spray missions on weight

Dependent variable	Z-score of weight-for-age							
Sample selection criteria 1	Within 5 standard deviations from the mean							
Sample selection criteria 2	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation method	IV	IV	IV	IV	IV	IV	IV	IV
Panel A: Second-stage results								
lnSpray	0.0131	0.0150						
	(0.0329)	(0.0336)						
lnAgent Orange			0.0176	0.0203				
			(0.0443)	(0.0460)				
lnAgent Blue					0.0527	0.0592		
					(0.1327)	(0.1343)		
lnAgent White							0.0239	0.0274
							(0.0597)	(0.0615)
Panel B: First-stage results								
D_Base	−0.1263***	−0.1284***	−0.0944***	−0.0944***	−0.0314**	−0.0325**	−0.0693***	−0.0702***
	(0.0314)	(0.0318)	(0.0271)	(0.0275)	(0.0128)	(0.0131)	(0.0212)	(0.0213)
F test of excluded instrument	16.12	16.25	12.08	11.79	6.03	6.18	10.63	10.77
R-squared of the first stage	0.0300	0.0308	0.0296	0.0291	0.0129	0.0138	0.0293	0.0299
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,064	11,354	12,064	11,354	12,064	11,354	12,064	11,354

Standard errors clustered at district level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Impacts of spray missions on Body Mass Index (BMI)

Dependent variable	Body Mass Index (BMI)							
Sample selection criteria 1	Within 5 standard deviations from the mean for height-for-age							
Sample selection criteria 2	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months	Full	Above 13 months
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation method	IV	IV	IV	IV	IV	IV	IV	IV
Panel A: Second-stage results								
lnSpray	0.1261**	0.1373**						
	(0.0638)	(0.0660)						
lnAgent Orange			0.1684*	0.1846**				
			(0.0861)	(0.0898)				
lnAgent Blue					0.5089*	0.5509*		
					(0.3039)	(0.3163)		
lnAgent White							0.2467*	0.2686*
							(0.1338)	(0.1396)
Panel B: First-stage results								
D_Base	−0.1296***	−0.1310***	−0.0971***	−0.0974***	−0.0321***	−0.0326***	−0.0662***	−0.0669***
	(0.0292)	(0.0292)	(0.0246)	(0.0247)	(0.0117)	(0.0119)	(0.0200)	(0.0200)
F test of excluded instrument	19.72	20.08	15.54	15.56	7.44	7.48	10.97	11.20
R-squared of the first stage	0.0302	0.0307	0.0290	0.0289	0.0127	0.0132	0.0259	0.0263
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,502	19,820	20,502	19,820	20,502	19,820	20,502	19,820

Standard errors clustered at district level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1