Factors Associated with Human Papillomavirus Infection Among Women in Health Region 10, Thailand: Evidence from HPV DNA Testing and GIS-Linked Spatial Decision Support

Chanpraw, W., Junnual, N. and Saenrueang, T.*
College of Medicine and Public Health, Ubon Ratchathani University, Thailand, E-mail: thitima.s@ubu.ac.th
**Corresponding Author*

DOI: https://doi.org/10.52939/ijg.v22i6.5042

Abstract
To determine factors associated with human papillomavirus (HPV) infection among women in Health Region 10, Thailand, and to integrate a GIS-linked spatial decision-support map for cervical cancer prevention. A cross-sectional analytical study used HPV DNA screening data collected between February and September 2023 among 2,086 women aged 20–59 years undergoing cervical cancer screening under the PP Fee Schedule program. Demographic, reproductive, behavioral, and laboratory data were retrieved from structured screening records and laboratory databases. Multiple logistic regression was applied to identify independent factors associated with HPV infection. HPV DNA screening results were aggregated at the provincial level and linked with administrative boundaries to produce a descriptive spatial decision-support map combining HPV positivity, screening volume, and planning signals. The prevalence of HPV infection was 15.1% (314/2,086). High-risk non-16/18 HPV genotypes predominated (11.4%), while HPV-16 and HPV-18 accounted for 2.6% and 1.1%, respectively. Women younger than 30 years had significantly higher odds of HPV infection (AOR = 2.67, 95% CI: 1.13–6.31), whereas a higher number of pregnancies was associated with lower odds of HPV positivity (AOR = 0.87, 95% CI: 0.78–0.97). Province-level mapping showed the highest positivity in Mukdahan (19.2%) and the largest screening volume in Ubon Ratchathani (n = 1,103). HPV infection was relatively common among women in Health Region 10. GIS-linked mapping can strengthen targeted screening, surveillance, and referral microplanning while avoiding unsupported cluster inference when only provincial aggregated data are available.

Keywords: Geographic Information Systems, Genotype Distribution, Human Papillomavirus, Risk Factors, Spatial Analysis

1. Introduction

Cervical cancer remains a major global public health challenge and is largely preventable through human papillomavirus (HPV) vaccination, regular screening, and timely treatment. In 2022, approximately 660,000 new cases and 350,000 deaths were reported worldwide, with the greatest burden concentrated in low- and middle-income countries [1]. The World Health Organization (WHO) has established a global elimination strategy based on 90–70–90 targets by 2030: 90% of girls fully vaccinated against HPV by age 15, 70% of women screened with a high-performance test by ages 35 and 45, and 90% of women with cervical disease receiving appropriate treatment [2].

In Thailand, cervical cancer continues to represent a major health burden among women, and recent national reviews describe cervical cancer as one of the most important female cancers requiring sustained screening and vaccination strategies [3]. Country-specific HPV and cervical cancer estimate also indicate continuing morbidity and mortality, underscoring the need for prevention strategies that are both clinically effective and geographically targeted [4]. WHO recommends HPV DNA testing as a primary cervical screening modality because HPV-based screening has higher impact than visual inspection with acetic acid or cytology for reducing cervical cancer morbidity and mortality when implemented at scale [5]. Thai evidence also supports the operational relevance of HPV testing and self-sampling approaches for improving screening access [6].

 © Geoinformatics International

Persistent infection with high-risk HPV genotypes is the necessary causal pathway for nearly all cervical cancers. HPV-16 and HPV-18 are globally dominant oncogenic types, but genotype distribution varies across regions and can influence vaccine and screening policy [7] and [8]. Evidence from Thai screening populations has shown that HPV-52 and other non-16/18 high-risk genotypes can be highly prevalent, indicating that genotype-aware prevention strategies are important for Thailand [9]. Health Region 10, located in Northeastern Thailand, comprises Ubon Ratchathani, Sisaket, Yasothon, Amnat Charoen, and Mukdahan provinces. The region contains rural and semi-urban populations, cross-border mobility corridors, and heterogeneous access to preventive services. These conditions make HPV prevention not only an individual-level epidemiological issue but also a spatially structured service-delivery problem involving screening coverage, laboratory access, transportation constraints, referral pathways, and local health-system capacity.

From a geoinformatics perspective, HPV prevention is spatially actionable. Geographic information systems (GIS) allow health data to be linked with administrative boundaries, service locations, road networks, and population denominators to support visualization, spatial pattern recognition, accessibility assessment, and evidence-based allocation of preventive resources [10] and [11]. For a geoinformatics journal, the value of GIS should therefore extend beyond routine mapping toward decision-support functions that translate health data into service-planning actions. Therefore, this study aimed to determine factors associated with HPV infection among women in Health Region 10 using real-world HPV DNA testing data and to develop a GIS-linked, province-level spatial decision-support map for cervical cancer prevention. The contribution of the study lies in integrating individual-level epidemiological analysis with a spatially interpretable planning layer that identifies where intensified surveillance, screening-resource concentration, and cautious interpretation are warranted.

2. Materials and Methods

2.1 Study Population

This cross-sectional analytical study used HPV DNA screening data collected between February and September 2023 in Health Region 10, Thailand. The study population comprised Thai women aged 20–59 years who received cervical cancer screening with HPV DNA testing under the PP Fee Schedule program. A total of 2,086 eligible women were included. Women with incomplete demographic data, missing laboratory results, or unclear HPV testing outcomes were excluded. The study protocol for analysis of these data was approved by the Ubon Ratchathani University Ethics Committee (Certificate No. UBU-REC-121/2567, dated 1 August 2024).

2.2 Procedure

Demographic and clinical information was retrieved from structured screening records and laboratory databases. HPV DNA testing results were classified as negative, HPV-16 positive, HPV-18 positive, or other high-risk HPV positive. The primary outcome was HPV positivity. Explanatory variables included age, health insurance scheme, history of hormonal contraceptive use, current contraceptive method, more than one sexual partner, history of sexually transmitted diseases, sexual debut before age 20, first childbirth before age 20, number of pregnancies, smoking status, and alcohol consumption.

2.3 GIS Linkage and Spatial Decision-Support Mapping

A GIS linkage framework was incorporated to translate HPV DNA screening results into spatial decision-support evidence for Health Region 10. Screening records were aggregated at the provincial level and linked to administrative boundary data for the five provinces of the region. Individual coordinates were not displayed or reported. The primary spatial indicator was HPV positivity rate per 100 screened women, calculated as the number of HPV-positive women divided by the number of screened women in each province and multiplied by 100. Screening volume was represented using proportional circles. To strengthen the geoinformatics contribution, the map was designed as a spatial decision-support product rather than as a conventional descriptive choropleth. Three operational signals were incorporated into the interpretation: high-positivity surveillance, regional screening hub, and small-sample caution. High-positivity surveillance was assigned to provinces with the highest observed HPV positivity; regional screening hub was assigned to the province with the largest screening volume; and small-sample caution was assigned to provinces where the screening volume was too limited for strong spatial interpretation. Spatial mapping was performed using a GIS workflow compatible with QGIS documentation and standard administrative-boundary linkage as shown in Figure 1.

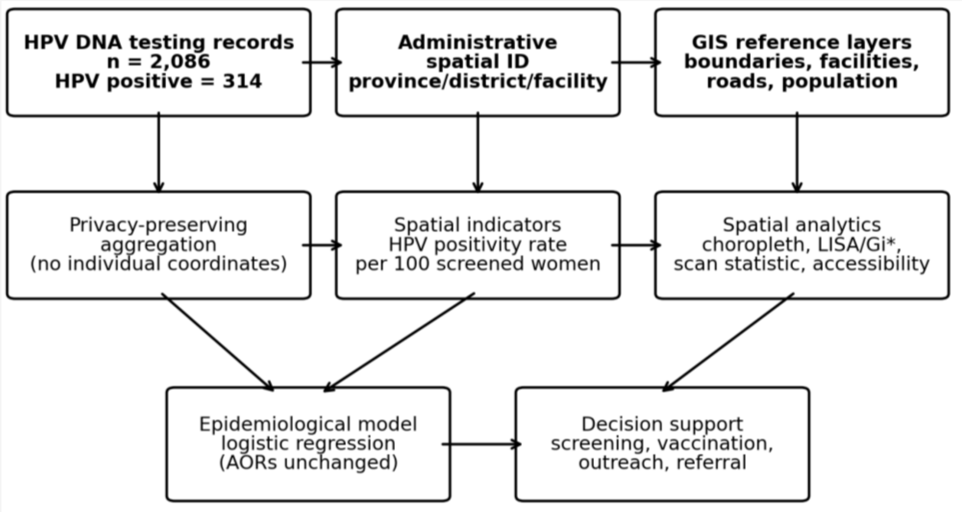

Figure 1: GIS-linked analytical workflow for translating HPV DNA testing data into spatial targeting actions in Health Region 10

Because the approved analytic file did not contain publishable district-level denominators, individual geocodes, health-facility locations, or road-network data, inferential spatial procedures were not performed in the present study. Global Moran's I, Local Moran's I, Getis-Ord Gi*, spatial scan statistics, and network-based travel-time accessibility analysis were treated as future extensions that would require finer spatial identifiers and service-network data [12][13][14][15] and [16].

2.4 Statistical Analysis

Descriptive statistics were used to summarize baseline characteristics. Continuous variables were presented as medians and interquartile ranges where appropriate, while categorical variables were reported as frequencies and percentages. Multivariable logistic regression was used to estimate adjusted odds ratios (AORs) and 95% confidence intervals (CIs) for factors associated with HPV positivity. Variables were selected based on theoretical relevance and univariate screening criteria. Statistical significance was set at $p < 0.05$. The GIS-linked component was reported as a descriptive spatial decision-support output rather than as inferential spatial cluster analysis.

3. Results

3.1 Individual-Level Characteristics, HPV DNA Results, and Associated Factors

According to Table 1, the total of 2,086 women were included. The median age was 43 years, with most participants aged 30–59 years (98.2%). The majority were covered by the Social Security Scheme (42.5%) or the Universal Coverage Scheme (38.4%). Most had never used hormonal contraceptives (76.1%) and were not currently using any method (82.2%), while oral contraceptive pills were the most common contraceptive method in use (11.2%). Regarding sexual and reproductive history, 5.9% reported more than one sexual partner, 8.7% had sexual debut before age 20, and 7.7% had first childbirth before age 20. The median number of pregnancies was 2. No participant reported a history of sexually transmitted disease. For lifestyle factors, 93.6% had never smoked and 85.2% had never consumed alcohol, while 2.7% were current smokers and 10.0% were current drinkers.

Among the 2,086 women screened for HPV, 314 (15.1%) were found to be HPV positive, while 1,772 (84.9%) tested negative as presented in Table 2. Regarding genotype-specific HPV prevalence in Table 3, 84.9% of participants tested negative. The predominant high-risk types were non-16/18 HPV genotypes (11.4%), followed by HPV-16 (2.6%) and HPV-18 (1.1%). In the initial model analysis, variables were selected based on literature relevance and univariate analysis with a p-value < 0.25. These variables were subsequently entered into the multivariable logistic regression model to identify potential predictors of HPV infection while controlling for confounding factors. Figure 2 shows that the women with a higher number of pregnancies had significantly lower odds of HPV infection (AOR = 0.87, 95% CI = 0.78–0.97, p = 0.010). Participants younger than 30 years had significantly higher odds of HPV infection compared with those aged 30–59 years (AOR = 2.67, 95% CI = 1.13–6.31, p = 0.025).

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

Table 1: Sociodemographic and behavioral characteristics of participants

Characteristic	N (%)
Age (years)	
< 30 years	37 (1.8)
30–59 years	2,049 (98.2)
Median = 43 (P25–P75: 36–50)	
Health insurance scheme	
Civil Servant Medical Benefit Scheme (CSMBS)	170 (8.2)
Local Government Employee Welfare	229 (10.9)
Social Security Scheme	886 (42.5)
Universal Coverage Scheme (UCS)	801 (38.4)
History of hormonal contraceptive use	
Never used	1,588 (76.1)
Used	498 (23.9)
Current contraceptive method	
Not using any method	1,714 (82.2)
Oral pills	233 (11.2)
Injectable	68 (3.3)
Implant	10 (0.5)
Condom	14 (0.6)
Sterilization	47 (2.2)
More than one sexual partner	
No	1,963 (94.1)
Yes	123 (5.9)
History of STD	
No	2,086 (100.0)
Yes	0 (0.0)
Sexual debut before age 20	
No	1,905 (91.3)
Yes	181 (8.7)
First childbirth before age 20	
No	1,925 (92.3)
Yes	161 (7.7)
Number of pregnancies	
Median = 2 (P25–P75: 1–2)	
Smoking status	
Never smoked	1,953 (93.6)
Former smoker	77 (3.7)
Current smoker	56 (2.7)
Alcohol consumption	
Never drank	1,778 (85.2)
Former drinker	99 (4.8)
Current drinker	209 (10.0)

Table 2: Prevalence of human papillomavirus (HPV) infection

HPV Infection Status	N (%)
HPV Negative	1,772 (84.9)
HPV Positive	314 (15.1)

Table 3: Results of HPV DNA testing by genotype

HPV Test Result	N (%)
Negative	1,772 (84.9)
HPV-16	55 (2.6)
HPV-18	22 (1.1)
HPV, non-16/18	237 (11.4)

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

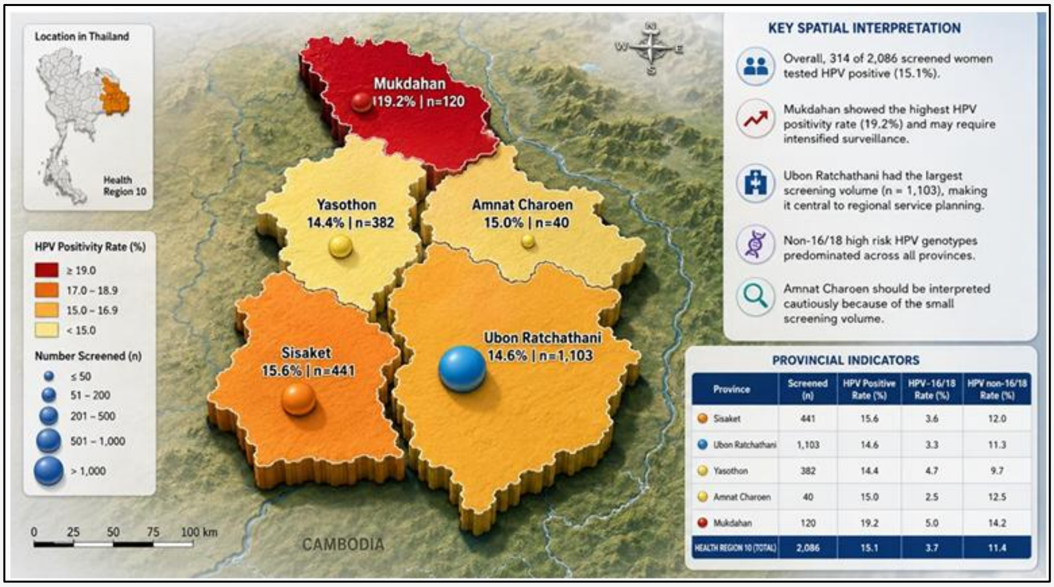

Figure 2: Province-level spatial distribution of HPV DNA positivity, screening volume, and spatial decision-support signals in Health Region 10, Northeastern Thailand

Note: HPV positivity rate was calculated as the number of HPV-positive women divided by the total number of screened women in each province and multiplied by 100. Circle size represents screening volume. Decision-support signals are descriptive planning categories and do not indicate statistically significant spatial clustering. Boundary data: Thailand Administrative Boundary COD-AB, Admin Level 1, Royal Thai Survey Department (2019). HPV DNA data were aggregated from the provincial screening table.

Table 4: Provincial indicators of HPV DNA screening outcomes in Health Region 10

Province	Screened (n)	HPV positive rate (%)	HPV-16/18 rate (%)	HPV non-16/18 rate (%)
Sisaket	441	15.6	3.6	12.0
Ubon Ratchathani	1,103	14.6	3.3	11.3
Yasothon	382	14.4	4.7	9.7
Amnat Charoen	40	15.0	2.5	12.5
Mukdahan	120	19.2	5.0	14.2
Health Region 10 (total)	2,086	15.1	3.7	11.4

3.2 Province-Level Spatial Distribution of HPV DNA Screening Outcomes

To make the HPV DNA screening results spatially actionable, province-level HPV positivity rates and screening volumes were mapped for the five provinces of Health Region 10. HPV positivity was visualized as a choropleth layer, whereas screening volume was represented using proportional circles. The map was also interpreted through planning signals to distinguish high-positivity surveillance, regional screening hub, small-sample caution, and monitoring or coverage-maintenance areas. Because only province-level aggregation was available, the map was interpreted descriptively and was not used to infer statistically significant spatial clustering. Figure 2 shows that HPV positivity and screening volume were unevenly distributed across Health Region 10. Mukdahan had the highest HPV positivity rate at 19.2%, although its screening volume was modest (n = 120), supporting intensified surveillance and follow-up verification. Table 4 illustrates that Ubon Ratchathani had the largest screening volume (n = 1,103), making it the main operational hub for regional screening logistics and referral coordination. Amnat Charoen had only 40 screened women and therefore requires small-sample caution and expanded screening before strong spatial conclusions are drawn. Sisaket and Yasothon showed intermediate positivity and moderate screening volumes, supporting continued monitoring and coverage maintenance.

4. Discussion

This study found that HPV infection was relatively common among women screened in Health Region 10, with an overall positivity rate of 15.1%. The

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

predominance of non-16/18 high-risk HPV genotypes is important because it indicates that regional prevention planning should not focus solely on HPV-16 and HPV-18. International and Thai evidence consistently shows that high-risk HPV genotype distribution varies by geography and population group, which has implications for screening triage, vaccine policy, and follow-up protocols [4][7][8] and [9].

Multivariable analysis demonstrated that younger women under 30 years had significantly higher odds of HPV infection. This finding is consistent with the natural history of HPV, in which incident infection is more frequent among younger sexually active women, although most infections clear spontaneously [1]. Higher number of pregnancies was associated with lower odds of HPV positivity in this dataset. This result should be interpreted cautiously because reproductive variables may be influenced by age, screening behavior, relationship patterns, and unmeasured confounding. Previous studies have reported heterogeneous associations between parity and HPV infection, indicating that local behavioral and demographic contexts are important [17] and [18].

The spatial decision-support map extends the epidemiological findings by translating HPV DNA testing results into operationally interpretable geoinformatics evidence. Rather than presenting GIS as a routine visualization, the map functions as a planning layer that combines HPV positivity, screening volume, and spatial caution. Mukdahan's higher positivity suggests a need for intensified surveillance and verification, while Ubon Ratchathani's large screening volume indicates its role as a regional service hub. Amnat Charoen illustrates the importance of sample-size caution in spatial health interpretation. This type of map is consistent with the public health use of GIS for linking disease patterns with service planning, resource allocation, and targeted intervention design [10] and [11]. Evidence from the International Journal of Geoinformatics further supports this health-GIS function. In Northeastern Thailand, a GIS-supported dengue hemorrhagic fever surveillance was modelled in Si Sa Ket Province. It integrated disease occurrence and environmental risk indicators for local disease-control planning [19]. Cancer-related GIS studies have similarly shown that disease mapping and healthcare-accessibility assessment can support targeted cancer-service planning [20] and [21].

Recent HealthGIS applications in Thailand have also demonstrated the value of GIS for emergency medical service coverage, infectious-disease prevention, and community health disparity and service-area analysis [22][23] and [24]. The present HPV study extends this locally relevant surveillance logic to cervical cancer prevention by translating HPV DNA screening outcomes into a province-level spatial decision-support layer for screening prioritization, follow-up verification, referral coordination, and cautious interpretation of small-sample areas. The strengths of this study include the use of HPV DNA testing, a large real-world screening dataset, and the integration of GIS-linked spatial interpretation into a cervical cancer prevention framework. The study also explicitly separates descriptive spatial decision support from inferential spatial cluster analysis, preventing unsupported hotspot claims. This distinction is important because province-level aggregation can inform service planning but cannot establish district-level clustering, individual risk, or causal spatial mechanisms.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference. Second, some behavioral variables were self-reported and may have been affected by recall bias or social desirability bias. Third, the study population was limited to Health Region 10, which may restrict generalizability to other Thai regions. Fourth, the spatial analysis was limited to province-level descriptive mapping. Because district-level denominators, individual geocodes, health-facility locations, and road-network data were not available in the approved analytic file, this study did not perform Moran's I, Local Moran's I, Getis-Ord Gi*, spatial scan statistics, or travel-time accessibility modeling.

Future research should employ longitudinal and spatially explicit designs to explore HPV persistence, genotype-specific trajectories, and geographic inequities in prevention access. District-level or subdistrict-level GIS analysis should be used to identify high-positivity clusters, underserved catchment areas, travel-time barriers, and service-referral gaps. Integrating HPV DNA screening data with vaccination coverage, population denominators, community health-volunteer outreach data, and health-facility capacity would allow cervical cancer prevention in Health Region 10 to evolve from descriptive mapping toward actionable spatial optimization.

5. Conclusion

HPV infection was common among women screened in Health Region 10, with younger age associated with higher odds of infection and higher number of pregnancies associated with lower odds. Non-16/18 high-risk HPV genotypes predominated across the region. Province-level GIS-linked mapping added a spatial decision-support layer by identifying Mukdahan as a high-positivity surveillance area, Ubon Ratchathani as the main screening-volume hub, and Amnat Charoen as a small-sample caution area. These findings support geographically differentiated screening, follow-up, vaccination promotion, and referral microplanning while preserving appropriate caution against unsupported spatial cluster inference.

Acknowledgements
The authors would like to thank the staff at the Health Promotion Hospital, Regional Health 10, and Ubon Ratchathani University for their support in this study.

References

[1] World Health Organization. (2025). *Cervical Cancer*. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/cervical-cancer. [Accessed: Jun. 18, 2026].

[2] World Health Organization. (2020). *Global Strategy to Accelerate the Elimination of Cervical Cancer as a Public Health Problem*. [Online]. Available: https://www.who.int/publications/i/item/9789240014107. [Accessed: Jun. 18, 2026].

[3] Wongpratate, M. and Bumrungthai, S., (2024). Cervical Cancer in Thailand: 2023 Update. *Obstetrics & Gynecology Science*, Vol. 67(3); 261–269. https://doi.org/10.5468/ogs.23277.

[4] ICO/IARC Information Centre on HPV and Cancer. (2023). *Thailand: Human Papillomavirus and Related Cancers, Fact Sheet 2023*. [Online]. Available: https://hpvcentre.net/statistics/reports/THA_FS.pdf. [Accessed: Jun. 18, 2026].

[5] World Health Organization. (2021). *WHO Guideline for Screening and Treatment of Cervical Pre-Cancer Lesions for Cervical Cancer Prevention*. 2nd ed., [Online]. Available: https://www.who.int/publications/i/item/9789240030824. [Accessed: Jun. 18, 2026].

[6] Sangrajrang, S., Pitakkarnkul, S., Muwonge, R., Ploysawang, P., Pangmuang, P., Seeda, K. and Basu, P., (2023). Agreement between Self- and Physician-Sampling for Detection of High-Risk Human Papillomavirus Infections in Women Attending Cervical Screening at National Cancer Institute, Thailand. *Asian Pacific Journal of Cancer Prevention*, Vol. 24(8); 2615–2619. https://doi.org/10.31557/APJCP.2023.24.8.2615.

[7] Muñoz, N., Bosch, F., X., de Sanjosé, S., Herrero, R., Castellsagué, X., Shah, K. V. and Fraumeni, J., F., (2003). Epidemiologic Classification of Human Papillomavirus Types Associated with Cervical Cancer. *New England Journal of Medicine*, Vol. 348(6); 518–527. https://doi.org/10.1056/NEJMoa021641.

[8] Bosch, F., X., Lorincz, A., Muñoz, N., Meijer, C., J., L., M. and Shah, K. V., (2002). The Causal Relation between Human Papillomavirus and Cervical Cancer. *Journal of Clinical Pathology*, Vol. 55(4); 244–265. https://doi.org/10.1136/jcp.55.4.244.

[9] Kantathavorn, N., Mahidol, C., Sritana, N., Sricharunrat, T., Phoolcharoen, N. and Auewarakul, C. U., (2015). Genotypic Distribution of Human Papillomavirus and Cervical Cytology Findings in 5906 Thai Women Undergoing Cervical Cancer Screening Programs. *Infectious Agents and Cancer*, Vol. 10(7). https://doi.org/10.1186/s13027-015-0001-5.

[10] Wang, F., (2020). Why Public Health Needs GIS: A Methodological Overview. *Annals of GIS*, Vol. 26(1); 1–12. https://doi.org/10.1080/19475683.2019.1702099.

[11] World Health Organization. (n.d.). *GIS Centre for Health*. [Online]. Available: https://www.who.int/data/GIS. [Accessed: Jun. 18, 2026].

[12] QGIS Documentation. (n.d.). *Documentation for QGIS 3.44*. [Online]. Available: https://docs.qgis.org/latest/en/docs/index.html. [Accessed: Jun. 18, 2026].

[13] Anselin, L., (1995). Local Indicators of Spatial Association LISA. *Geographical Analysis*, Vol. 27(2); 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x.

[14] Getis, A. and Ord, J. K., (1992). The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis*, Vol. 24(3), 189–206. https://doi.org/10.1111/j.1538-4632.1992.tb00261.x.

[15] Kulldorff, M., (1997). A Spatial Scan Statistic. Communications in Statistics. *Theory and Methods*, Vol. 26(6); 1481–1496. https://doi.org/10.1080/03610929708831995.

[16] Luo, W. and Wang, F., (2003). Measures of Spatial Accessibility to Health Care in a GIS Environment: Synthesis and a Case Study in the Chicago Region. *Environment and Planning B: Planning and Design*, Vol. 30(6), 865–884. https://doi.org/10.1068/b29120.

[17] Okunade, K. S., Oluwole, A. A., Anorlu, R. I. and Oyekan, T. O., (2017). Prevalence and Risk Factors for Genital High-Risk Human Papillomavirus Infection among Women Attending the Out-Patient Clinics of a University Teaching Hospital in Lagos, Nigeria. *Pan African Medical Journal*, Vol. 28. https://doi.org/10.11604/pamj.2017.28.227.11979.

[18] Taku, O. B., Mdaka, B. C., Phohlo, K., Basera, W., Garcia-Jardon, M., Meiring, T. L., Williamson, A. L. and Mbulawa, Z., Z., A., (2020). Human Papillomavirus Genotype Distribution among HIV-Negative Women in South Africa: A Cross-Sectional Study. *BMC Cancer*, Vol. 20. https://doi.org/10.1186/s12885-020-07049-z.

[19] Wongpituk, K., Kalayanarooj, S. and Nithikathkul, C., (2020). Geospatial Analysis of DHF Surveillance Model in Si Sa Ket Province, Thailand using Geographic Information System. *International Journal of Geoinformatics*, Vol. 16(3), 97–104. https://ijg.e-geoinfo.com/index.php/journal/article/view/1785.

[20] Harinthiran, V., Zain, W. Z. W., Zakaria, A., Hayati, M., Ismail, A., Kaur, N. and Abdullah, N., (2021). Geographic Information System (GIS) in Evaluating the Accessibility of Healthcare Facility for Patients with Colon and Rectal Carcinoma in the State of Kelantan and Sabah. *International Journal of Geoinformatics*, Vol. 17(4); 49–59. https://ijg.e-geoinfo.com/index.php/journal/article/view/1951.

[21] Zuhdi, N., Rahman, W., Damitri, T., Ismail, A. and Hassan, R. (2021). Geospatial Analyses of Thyroid Cancer Incidence in Kelantan, Malaysia. *International Journal of Geoinformatics*, Vol. 17(5); 130–139. https://doi.org/10.52939/ijg.v17i5.2025.

[22] Thipthimwong, K., Panawathanapisuit, S., Thonthong, T., Yamsri, T. and Plubplatong, T. (2024). A Geographic Information Systems-Based Analysis of Response Time and Hospital Coverage Area in Sukhothai Province, Thailand. *International Journal of Geoinformatics*, Vol. 20(8); 46–55. https://doi.org/10.52939/ijg.v20i8.3449.

[23] Kanjaras, P., Bumrerraj, S., Seng, R., Noradee, S. and Nithikathkul, C. (2023). Geospatial Analysis and Modeling of Melioidosis Prevention and Control in Si Sa Ket Province, Thailand. *International Journal of Geoinformatics*, Vol. 19(1); 57–65. https://doi.org/10.52939/ijg.v19i1.2501.

[24] Piwpong, R., Sujayanont, P., Jundaeng, J., Krates, J., Kijphati, R. and Nithikathkul, C. (2025). Applications of GIS in Analyzing Health Disparities Among the Elderly and Health Center Service Area Coverage: Community Model, Lahansai District, Buriram, Thailand. *International Journal of Geoinformatics*, Vol. 21(4); 131–148. https://doi.org/10.52939/ijg.v21i4.4075.