A Mapping Review on Urban Landscape Factors of Dengue Retrieved from Earth Observation Data, GIS Techniques, and Survey Questionnaires

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Abstract: To date, there is no effective treatment to cure dengue fever, a mosquito-borne disease which has a major impact on human populations in tropical and sub-tropical regions. Although the characteristics of dengue infection are well known, factors associated with landscape are highly scale dependent in time and space, and therefore difficult to monitor. We propose here a mapping review based on 78 articles that study the relationships between landscape factors and urban dengue cases considering household, neighborhood and administrative levels. Landscape factors were retrieved from survey questionnaires, Geographic Information Systems (GIS), and remote sensing (RS) techniques. We structured these into groups composed of land cover, land use, and housing type and characteristics, as well as subgroups referring to construction material, urban typology, and infrastructure level. We mapped the co-occurrence networks associated with these
factors, and analyzed their relevance according to a three-valued interpretation (positive, negative, non significant). From a methodological perspective, coupling RS and GIS techniques with field surveys including entomological observations should be systematically considered, as none digital land use or land cover variables appears to be an univocal determinant of dengue occurrences. Remote sensing urban mapping is however of interest to provide a geographical frame to distribute human population and movement in relation to their activities in the city, and as spatialized input variables for epidemiological and entomological models.

**Keywords:** Dengue; Urban landscape; environment; remote sensing; interdisciplinary

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1. Introduction

Around half of the global population is exposed to the risk of dengue virus transmission [1]. This risk exists in nearly a hundred countries, with an estimated 390 million cases per year worldwide [2]. Urban areas are particularly at risk because of (i) the larval habitats of the *Aedes* mosquitoes [3–5] (ii) the high density of human populations, and (iii) the multiplicity of migration and commuting patterns, that could be catalysts for the rapid spread of infectious diseases [6].

 Worldwide, *Aedes aegypti* is the primary vector of the virus that causes dengue, while *Aedes albopictus*, a homologous species with a lesser vector competency, is responsible for large dengue epidemics in southeast Asia [7]. The authors of Reference [8] have shown that *Aedes* distributions are currently the widest ever recorded, and are now extensive in all continents, including North America and Europe. Both species have become increasingly capable of exploiting man-made container habitats and human blood meal hosts [9,10], demonstrating their high-level of ecological plasticity and remarkable adaptation to urban settings [11]. The abundance and distribution of *Aedes* mosquitoes are influenced by climatic, topographic, land use and land cover (LULC) factors [10]. The relationship between entomological indicators of *Aedes aegypti* abundance and dengue virus infection is not straightforward [12], and it is difficult to identify a minimal entomological threshold for dengue transmission [13]. This is probably due to (i) the remarkable capacity of *Aedes aegypti* to survive and efficiently transmit the dengue virus even over low population densities [14] (ii) the irregularity of dengue epidemic patterns influenced by serotype dynamics and herd immunity at various level scales [15,16], and (iii) the competence of *Aedes aegypti* to transmit the dengue virus which is highly variable and depends on exogenous factors [12]. Urbanization has substantially increased the density, larval development rate, and adult survival time of *Aedes albopictus*, which in turn has potentially increased the vector capacity [4,17]. Many of the *Aedes* control strategies in development will have time-lagged impacts on adult populations ([18], e.g., Wolbachia and transgenics).

The complex association between the dengue virus (DENV), humans, and *Aedes* populations leads to the question of an appropriate geographic scale to measure the importance of the risk factors, as parameters and processes at a given scale are frequently not important or not predictive at another scale [13]. In the case of vectorial diseases, space may be seen as (i) an actor through the numerous spatially-dependent determinants (environmental, socio-economic, climatic) that influence the spread of the pathogen, and (ii) a medium where humans, reservoirs and vector populations interact and allow the circulation of the pathogen [19]. Although most dengue risk factors are likely to exhibit spatial dependence [13,20], few articles have applied spatial analysis methods in dengue studies [21]. Of the 263 articles on dengue outbreaks reviewed in the literature by Guo et al. [22] over the 1990–2015 period, around twenty deal with spatialized and environmental risk factors. The lack of information on the explicit spatial relationships between human and vector encounters and virus exposure have become a complicated challenge to prevention programs due to the lack of specific targets for vector control. Transportation networks, human mobility and socially structured human movements might shape dengue transmission [23]. The heterogeneity of a urban landscape could influence the biologically-relevant
parameters that define vectorial capacity, through habitat suitability, socio-ecological processes and local temperature variations such as urban heat islands (UHI) [24]. However, the impacts of landscape structure on epidemiological processes have been largely neglected in the past [25], and there is still a need for a spatialized integrated approach at various spatial scales [20,24], to combine methods from epidemiology, ecology, statistics and geographic information sciences [25–27].

Over the last twenty-five years, advancement in spatial epidemiology has been largely driven by the use of Geographical Information Systems (GIS) and georeferencing data systems [28,29]. In the case of vector-borne diseases, it may also include remote sensing techniques, which present a high-potential in disease risk mapping and environmental contextualizing [30–33], but probably still remains underutilised [34,35]. Remote sensing uses the notion of a proxy, that is a measurable variable which represents an indirect measure of an impractical physical variable that cannot be measured directly [35]. In the case of vector-borne diseases, entomological data surveys are often costly, labor-intensive and remain scarce [13,36]. Therefore, authors often use the proxies of mosquito breeding or resting sites based on the vector-knowledge reviewed in the literature [17,37]. Despite a more systematic use of GIS and the implementation of spatial statistical methods, the availability of health data and appropriate exposure data often remain limiting factors [38]. National passive notification systems present high variability in the standard of data and metadata storage, which highlights the importance of local knowledge through seroprevalence survey and questionnaire-based responses that can help to add clarity in uncertain regions [39].

We propose here a mapping review to create an inventory and identify the most relevant landscape factors potentially involved in dengue transmission in urban contexts from different data sources. Mapping reviews enable the contextualization of in-depth systematic literature reviews within broader literature and identification of gaps in the evidence base [40]. Mapping reviews share common purposes with scoping reviews, such as examining how research is conducted and structured on a certain topic, the identification of available evidence and the investigation of knowledge gaps [41,42], but provide a systematic map representation to categorize the included articles. Taking an interdisciplinary view, we propose a systematic search of articles into the literature to:

(i) identify the landscape factors according to various sources and geographical units of production;
(ii) map co-occurrence networks associated with the landscape factors, in order to identify the potential underlying structure of fields;
(iii) evaluate qualitatively the respective importance of the above for the mapping of the dengue risk.

2. Material and Methods

2.1. Systematic Search of Articles

This systematic review used the guidelines presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [43]. The methodology is summarized in Figure 1 and the detailed steps are presented hereafter. Data at the identification and the screening process steps were extracted by two independent researchers (RM and ZL), and discrepancies were resolved concordantly. The searches were performed in four on-line bibliographic databases, from inception to 31 December 2019:

1. **Science Direct**: e.g., *Annals of Epidemiology, of Global Health, of Tropical Biomedicine, International Journal for Parasitology, Acta Tropica, Infectious Disease Clinics of North America, etc.*
2. **Web of Science**: e.g., *International Journal of Environmental Research and Public Health, Asian Pacific Journal of Tropical Medicine, Environment Development and Sustainability, International Journal of Environmental Research and Public Health, Journal of Medical Entomology, etc.*
3. **PubMed**: e.g., *International Journal of Health Geographics, PLOS Neglected Tropical Diseases, The Brazilian Journal of Infectious Diseases, etc.*
4. **Scopus**: e.g., *e.g.*, *Asia Pacific Journal of Public Health, BMC Infectious Diseases, Epidemiology and Infection, Geocarto International, etc.*

and considered either “all fields” (including bibliography references) or only “title-keywords-abstract” according to the database query form, and limited to the type “journal article”. The logical structure of the queries was based on the following formula:

(i) dengue AND (urba* OR cit*) AND (“land use” OR “land cover” OR landscape OR dwelling OR habitation)

The character * being the classical symbol for regular expressions, corresponding to any character or group of characters, for example, urba* refers to the words urban, urbanization, and so forth. No constraints on the study period and language were imposed in the search queries. All search records from the four on-line databases were then combined together \( n = 2342 \), using the free and open-source reference management software Zotero (https://www.zotero.org/). In addition, a search in Google Scholar® was done to avoid the omission of relevant articles \( n = 272 \). Duplicates \( n = 311 \) were automatically removed from the \( n = 2614 \) combined records leading to \( n = 2303 \) at the end of the identification stage.

**Figure 1.** Stages of systematic search to retrieve included article to our four criteria, following the PRISMA statement [43].

2.2. **Screening, Selection Criteria, Risk of Bias, and Contribution of the Articles**

A systematic checking of the titles and abstracts was conducted in order to select only the peer-reviewed original research articles dealing with the relationships between landscape factors and dengue cases, leading to \( n = 234 \) at the end of the screening step, excluding those deemed irrelevant to the topic. Based on a full text reading, screened studies at the previous step were included if:

(i) they consider geographical units within a city;
(ii) they included spatialized dengue cases, collected by passive notification systems or by serological surveys;

(iii) they identified and characterized the influence of landscape factors on dengue occurrences in an urban context;

(iv) they described the explicit relationships between landscape classes and dengue data.

In contrast, studies that:

(i) consider rural areas, or include large part uncovered by urban areas;
(ii) do not consider dengue occurrences, but solely Aedes mosquitoes as proxy of dengue presence;
(iii) do not include any explicit landscape feature, for example, solely consider meteorological variables (temperature, wind speed etc.) or socio-economic variables (income, status etc.);
(iv) do not bring any evidence or information on the used models to perform the relationship between dengue occurrences and landscape features;

were excluded, which finally resulted in [n = 78] articles included in the review, at the end of the eligibility step. A total of 156 articles were discarded at the end the screening stage based on criteria 1 (does not consider an urban geographical unit of a city, [n = 36]), criteria 2 (does not consider spatialized dengue cases [n = 26]), criteria 3 (does not consider at least one landscape factor, [n = 31]), criteria 4 (does not perform a relationship between dengue and landscape, [n = 49]), or based on an insufficiently described methodology ([n = 13]).

We considered landscape factors in a “broad” definition, centering around a virus perspective: vectors and humans are hosts, and their respective trajectories lead to a complex interaction, which facilitate or hamper the virus circulation. Therefore, we considered entomological variables and human densities or movements as dynamic features of the landscape. On the other hand, we limited our definition of landscape factors to physical variables, and discarded direct references to socio-economic data, as level of income, per capita gross domestic product (GDP), or unsatisfied basic needs. We have in the first place considered a “Built City”, i.e. a city as a physical entity, or the area devoted to primarily urban uses [44]. Such definition is in line with the global urban mapping approaches, and automatic extraction of built-up area [45–47]. As a proxy of human presence and Aedes habitats, urban areas within a city reflect a “certain density” of buildings, which threshold varies according to the geographical context and authors definition, out of the scope of this paper. We did not have either considered the question of city size, an issue of considerable significance in urban and regional analysis.

Various methods exist to appraise the quality of studies included in a review, and assess the corresponding risk of bias. These methods differ greatly in applicability across study designs, and approaches: e.g., scale vs checklist, presence/absence of summary score etc. [48]. During the screening stage, we performed a first “minimum quality threshold associated to the thematic criteria” (Figure 1) in order to discard articles were the data set or the methodological descriptions remain unclear. At the eligible stage, we included a checklist on key features of the 78 included articles based on a four-valued choice (“yes”, “no”, “partial”, “can’t tell”) to characterize (i) the completeness of the epidemiological and the entomological dataset (ii) the degree of maturity of the methods to produce the landscape factors (iii) the characterization of the dengue–Landscape relationship. We also provide an overall appraisal of the level of contributive information respect to the topic “dengue–relationship characterization” (from 1: high to 4: poor). These information are available in a table format as Supplementary Materials.

Our entire bibliographic database, structured according to the PRISMA steps, may be consulted at the following web address: https://www.zotero.org/groups/2159925/article-review_dengue_landscape/items/collectionKey/. By browsing the Zotero folders, readers could see the different results obtained through the systematic requests on the one-line databases, and by picking one particular article in the “non eligible” folder, readers could visualize the reason associated to the inclusion/exclusion decision in the note section (right window in the online application).
2.3. Structuring of the Information Extracted from the Included Articles

We referenced the included articles by an identification (id) number assigned alphabetically from 1 to 78, which corresponded to reference numbers [135] (Ali et al., 2003) to [212] (Zellweger et al., 2017) in the bibliography section (please refer to the appendix for a full description). We manually extracted the information concerning the data, the methods, and the main results to build three analysis tables, according to the following categories (please refer to the appendix section for exhaustive tables):

(i) the geographical context: country, study area (city), geographical unit of spatial analysis (Table 1 and Appendix A);
(ii) the epidemiological descriptors: start and end years of an outbreak or survey, dengue data type (incidence, prevalence, case number), medical analysis to confirm the diagnosis (clinical signs, laboratory analysis), number of dengue cases (and incidence rate when available), spatial variation and pattern(s) observed, vector species involved (Table 2 and Appendix A);
(iii) the landscape factors: data source according to three subcategories: remote sensing images (sensor name), Geographic Information System (GIS) layers, and survey questionnaires. We also extrapolated the type of proxy associated (i.e., the element of the transmission cycle represented, for example, “exposure to Aedes bite”), and the type of data (e.g., land use or housing type and characteristics) according to a two-level classification, called data group and sub-group, respectively (Table 3 and Appendix A);
(iv) the search of a relationship between urban determinants and dengue cases: type of statistical and spatial methods used to quantify the relationship between dengue cases and environmental determinants, interpretation of the relationship through a three-valued index: positive (+), negative (−), or non-significant (NS) (Table 3 and Appendix A).
Table 1. Structuring of the data extracted from the articles on the publication meta-data and the geographical context. First line (id: 3) is given as an example. Please refer to the annex-table 1 for the whole dataset ([n = 78] articles).

| ID | Author | Date | Title | Journal | Country | City | Geographical Unit of Spatial Analysis |
|----|--------|------|-------|---------|---------|------|---------------------------------------|
| 3  | Araujo | 2015 | Sao Paulo urban heat islands have a higher incidence of dengue than other urban areas | The Brazilian Journal of Infectious Diseases | Brazil | Sao Paulo | Districts |

Table 2. Structuring of the data extracted from the articles on the epidemiological context. First line (id: 3) is given as an example. Please refer to the annex-table 2 for the whole dataset ([n = 78] articles). In last column, we indicate if vectors are only mentioned (M) or observed (O) in the study.

| ID | Start–End Years | DATA Source | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|----|-----------------|-------------|-------------------|-----------|-----------------|------------------|----------------|
| 3  | 2010–2011       | Passive notification (COVISA) | IgG (ELISA) | NA | N = 7415 | Heterogeneous | Aedes aegypti (M) |

Table 3. Structuring of the data extracted from the articles on the landscape factor production and the dengue-landscape relationship. First line (id: 3) is given as an example. Please refer to the annex-table 3 for the whole dataset ([n = 78] articles).

| ID | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|----|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------------|-------------------|
| 3  | Landsat 5 TM image | Land cover | Surface Temperature | Urban heat islands | + | Vectors resting sites and virus replication (at large-admin level) | Multiple cluster analysis |
2.4. Analysis and Representation of the Information

2.4.1. Cartographic Representation

Based on the information extracted from the geographical context and the epidemiological information, we mapped the cities corresponding to the 78 study sites (QGIS LTR 3.4). We distinguished the types of epidemiological data according to their sources: passive surveillance system, or serological studies (incidence or prevalence). We also mapped the techniques employed to produce the information related to landscape factors: survey questionnaire, GIS data, and remote sensing imagery.

2.4.2. Co-Word Analysis through Self-Defined Tags Co-Occurrences

To understand how landscapes factors are produced and those that could be critical in urban dengue transmission, we adapted a method derived from bibliometric visualization techniques (Figure 2). Such approaches are based on the mapping of a network, which represents the degree of keyword co-occurrence of predefined article descriptors, like co-authors, or tags. Co-word networks may help to identify the conceptual structure, that uncovers links between concepts through term co-occurrence. Promising implementations of such literature analysis tool have been recently developed ([49,50], NAILS, bibliometrix). To perform this network mapping, here we used VOSviewer software (V1.6.11), a tool for constructing and visualizing bibliometric networks [51], and already used to perform review analysis ([33], e.g., Remote Sensing in Human Health). To map the structure associated with the landscape factor production, we exported the bibliographic references according to three categories: remote sensing images, GIS data, and survey questionnaire. From the bibliometric manager (Zotero 5.0.73), we chose a standardized tag format developed by Research Information Systems (RIS), compatible with VOSviewer and the module create map based on bibliographic data. To map the networks, we chose Co-occurrences with Keywords as units of analysis, associated with the full counting method. Here, keywords refer to self-defined tags, identified by the authors of this review, and associated with landscape factors, structuring terms, and a three-valued interpretation associated with the dengue-landscape relationship (positive, negative, or non-significant) (Figure 2). We defined the minimum number of occurrences as 1, in order to map the entire landscape factor network. Here, a node is associated with a tag (or keyword), with an edge representing a link of co-occurrence between two tags. To map the networks associated with the nature of the relationships between the landscape factors and the observed dengue cases, we adopted the same approach for each of the four defined spatial units: household, neighborhood, small-administrative, large-administrative (including city-level (Figure 2). As VOSviewer is mainly designed to visualize large maps containing thousands of items, it could have been challenging to read the full-network, so we added a post-treatment step, in order to make some items more readable by modifying the character font (Inkscape, version 0.92.4).

Survey questionnaires and census data originate from socio-geographical approaches, while entomological observations are part of medical entomology. As these were mainly collected during household investigation, they were associated it with survey questionnaires in the data structure representation, as part of socio-ecological surveys.
3. Results from Information Extraction

3.1. Geographical and Epidemiological Contexts

Temporality and location of the included articles (Figure 3):

- The oldest article was published in 1986, and refers to a dengue transmission episode observed in two Puerto Rican communities which occurred in 1982 (id: 73). Four articles were published in the 1990s, and refer to putative determinants and predictors of infection in Mexico (id: 34), risk factors observed in Puerto Rico (id: 55), determinants of dengue-2 infection in Australia (id: 43), and relationship between Breteau, House index (HI), and occurrences of dengue in Malaysia (id: 60);
- Twenty articles were published between 2000 and 2009, mainly in Brazil (ids: 18, 27, 28, 46, 61, 62), Central America (ids: 7, 9, 12, 21, 25, 52, 69), South America (id: 56), South and East Asia, Bangladesh (id: 1), and Thailand (ids: 65, 70, 71). Two articles were published in West and Central Pacific, Palau (id: 4), and Hawaii (id: 26);
- From 2010 and before 2015, we identified 16 articles, which were concerned principally with Central and South America: Costa Rica (id: 44), Colombia (id: 45), Ecuador (id: 59), and Brazil (ids: 5, 6, 8, 48), East Asia: in China (ids: 15, 36, 74), in Malaysia (id: 19, 75), in Thailand (ids: 35, 57), and in the Philippines (id: 23). One of the two articles published in the Middle East (Saudi Arabia) was from 2011 (id: 32);
- Since 2015, the majority of the thirty-seven study sites were located in South Asia, mainly in China (ids: 10, 13, 14, 16, 29, 37, 39, 50, 51, 53, 66, 76), India (id: 41, 63) and Pakistan (id: 40), and South East Asia: Vietnam (ids: 33, 68), Singapore (ids: 24, 58, 77), Malaysia (id: 67), and Indonesia (ids: 31, 49, 54, 72). Five articles since 2105 related to Central and South America: Mexico (id: 22),...
Brazil (ids: 3, 47), Argentina (id: 11), Colombia (ids: 17, 42), and Ecuador (ids: 30, 38). We found only one article concerning Africa (Kenya), published in 2016 (id: 20), and the second article of the Middle East (Saudi Arabia) which was from 2019 (id: 2):

- Various articles concern urban areas located in an insular context: Palau in the western Pacific (id: 4), Puerto Rico (id: 55), Hawaii (id: 26), Singapore (ids: 24, 77), Taiwan (Province of China) (ids: 15, 16, 74), Trinidad (id: 12) and New Caledonia (ids: 64, 78). Two studies make a cross-border comparison, between USA and Mexico border-cities (ids: 9, 52);

- Most study sites are limited to a unique city, excepted in some cases, which consider various urban areas (id: 2, multi-stage stratified cluster sampling in four cities of Saudi Arabia), (id: 34, serosurvey in 70 localities of Mexico), (id: 44, correlational epidemiological study conducted in the country’s 81 cantons of Costa Rica), (id: 45, 30 selected municipalities of Colombia’s Córdoba Department), (id:50, seven cities of the Guangdong province, located at the Pearl River estuary) (id: 67, various degrees of urbanization between cities in Malaysia), (id: 64, different elevation levels in New Caledonia);

- Ten articles focused on the city of Guangzhou, located in the south-central part of Guangdong Province in China (ids: 10, 13, 14, 36, 37, 39, 51, 53, 66, 76). Guangzhou is considered as “the center of transportation, finance, industry and trade in southern China and has frequent economic and cultural communication with the nations of Southeast Asia and Africa” (id: 14). If historically, dengue fever has re-emerged in China in 1978 from its first appearance in Foshan city (Guangdong province), Guangzhou, with its 14.49 millions resident population, has “always been the hardest hit area of [dengue fever] DF in Guangdong Province and China”, with epidemic episodes that have “gradually intensified” (ids: 14, 39);

- Collectively, these review articles propose a broad spatial sampling of the inter-tropical belt, traditionally associated with dengue occurrences [2], and consider dengue cases observed over a thirty seven year time-span, between 1982 and 2019 (Figure 3).

**Epidemiological characteristics of the included articles:**

- The dengue virus can cause a large range of symptoms, ranging from an asymptomatic form, which includes the vast majority of infections, and may be associated with various degrees of infection: dengue fever (DF), dengue hemorrhagic fever (DHF) to the potentially fatal dengue shock syndrome (DSS) [52]. Generally, most articles refer to dengue cases that include a broad interpretation of the disease expression, especially fever (DF). Twelve studies in the method section refer explicitly to DHF cases (ids: 7, 12, 17, 25, 31, 38, 49, 59, 60, 65, 75, 68), and two to DSS (id: 31, 65). In Indonesia for example, only DHF cases are mandatorily reported (id: 49);

- We identified 23 articles based on serological surveys performed by the authors (ids: 2, 7, 8, 9, 20, 22, 26, 28, 30, 34, 35, 43, 48, 49, 52, 55, 61, 67, 70, 71, 73, 75, and 77). In such approaches, based on fieldwork, household location is used to spatially identify the dengue cases. Fifty-five other articles were based on passive notification of cases collected by local and national health agencies. Such databases may collect the patient address or refer to an administrative division to locate the cases, without further information on a potential place of transmission (ids: 15, 16, 19, 23, 32, 35, 57, 64, 66, 78). A geocoding step is necessary where patients home addresses are available to associate (X, Y) coordinates in a GIS;

- Geocoding was performed manually (ids: 3, 54, 65, 67, 69) or probably manually (ids: 11, 18, 17, 31), and in 5 cases by an automatic method (id: 42 R script-ArcGIS server, ids: 37 and 53 http://www.gpsspg.com/xGeocoding/) or probably automatic method (id: 46 MapInfo, id: 76 not described method). The authors may decide to spatially aggregate the dengue cases at a coarser resolution to perform the association with other data sources (id: 10, “Gross Domestic Product” at township/street level; id 38, census block);

- Considering the temporal aspect, 26 articles use datasets, which cover at most three years. The longest time series of dengue cases was an uninterrupted 22 years dataset in the city of Guangzhou,
China, from 1978 to 2014 (id: 66). Most publications aggregated dengue data and calculated the yearly average incidence rate;

- Almost all of the 78 publications included articles which confirmed a highly non-uniform spatial distribution in the urban context, regardless of the spatial scale of analysis. Global or focal cluster detection are commonly based on global/local Moran’s index to detect the presence of overdispersion based on autocorrelation analysis [53], and is based on either a sliding circular window (cylinder, if the time dimension is considered), or consider each spatial unit towards contiguous neighbor units (ids: 10, 16, 17, 18, 38, 46, 54, 58, 65, 78). Its value comprises between [-1,+1], and reflects the assumptions about the spatial phenomenon in question to detect negative or positive spatial auto-correlation. In the articles of this review, a local Moran’s index often highlights the presence of a spatial correlation at fine scale. Various articles identify clusters (ids: 1, 3, 10, 16, 17, 18, 24, 31, 36, 37, 38, 39, 46, 51, 53, 58, 63, 65, 70, 71, 74, 78), hotspots (ids: 10, 19, 50, 56, 59) and coldspots (id: 10, 50). In one study (id: 42), the authors tested several structures of spatially explicit Bayesian models in order to estimate the relative risk (RR) of dengue.

**Entomological consideration in the included articles:**

- The majority of the articles only mention the implication of the *Aedes* vector in the introduction and/or the discussion sections, and exclude entomological consideration in the method or in the data acquisition. Nineteen articles performed entomological observations of: *Aedes aegypti* (ids: 1, 4, 5, 6, 9, 24, 26, 28, 34, 52, 55, 58, 60, 61, 73), *Ae. albopictus* (ids: 1, 4, 9, 26, 58, 60, 66), or of *Ae. (Stegomyia) genus* (ids: 12, 25, 65) without distinction between both species;

- Thirty-six articles mentioned *Aedes aegypti* as the main or exclusive vector, six mentioned *Ae. albopictus* as the main or exclusive vector (ids: 10, 13, 39, 50, 51, 53), and ten mention both or just the *Ae. (Stegomyia) genus* as responsible for the dengue transmission process (ids: 14, 16, 36, 41, 49, 54, 57, 67, 74, 75). Only one study dispensed with an entomological database prior to the survey, made available by the infectious disease surveillance system (id: 66, Notifiable Infectious Disease Report System (NIDRS), Guangzhou);

- The potential heterogeneous nature of the spatial dispersion of mosquito density has been analysed in some studies (in relation with the dengue occurrences), through, notably (i) the intensity of larvae-positive breeding sites by properties inspected in each block, using the kernel estimator method (id: 5), parameterized with a flight distance of 280 m which is associated with the *Aedes aegypti* female [54], (ii) the extrapolation by ordinary kriging of entomological indicators associated with the four life stages of *Ae. aegypti*: (absolute) number of *A. aegypti* eggs in the block, and number of positive buildings for *Ae. aegypti* larvae-pupae and adults in the block, divided by the number of buildings surveyed in the block (id: 6).
Figure 3. Top: localization and characteristics of the epidemiological data sets of the 78 articles of the review. We indicate the type of sources (serological surveys or passive notification system) and the temporal range associated with the dengue data. Bottom: localization and characteristics of the landscape data sets of the 78 articles of the review. We indicate the type of sources: questionnaire surveys, GIS, Remote sensing data, and the availability of entomological data (*)..
3.2. Production of the Landscape Factors Associated to Dengue Cases

**Type of approaches:** We identified five approaches that led to the production of landscape characteristics (Figures 3 and 4):

- (i) Survey questionnaire, including census data;
- (ii) \textit{in situ} entomological observation;
- (iii) Geographical Information system (GIS) data;
- (iv) Topographical measurements;
- (v) Remote sensing data (RS data), originated from satellite images.

**Data sources network considering all approaches:** The graphical representation of the data sources network, considering all type of data, highlights the strong polarization between “survey questionnaire” and “remote sensing images” (Figure 4):

- “RS images” are strongly connected to the “land cover” properties of the environment, while “survey questionnaire” is strongly connected to “housing characteristics”, “housing type”, “construction material” and “entomological observation”. “GIS data” sources are both connected to “remote sensing images” and “survey questionnaire”, highlighting its interface position as a bridge between human geography approaches and digital geography (e.g., [55]);
- “GIS data” connect well to the “land use” characteristics of the environment, the “infrastructure level” and the “typology” of the urban area. It is noteworthy that the node “\textit{Aedes aegypti} mention” is at the centre of the network, which shows that entomologist information relative to the 78 included studies, centred on observed dengue cases, are coming from a knowledge base of the mosquitoes rather than direct observations. Entomological observations concerning \textit{Aedes aegypti} and \textit{albopictus}, considered together or separately, belong to the “survey questionnaire” cluster, while \textit{Aedes aegypti} and \textit{Ae. albopictus} mentions belong to “remote sensing image” or “GIS data” clusters (Figure 4);
- Considering the publication year associated with the data source (Figure 4), it is noteworthy that “survey questionnaire” and “entomological observations” are associated with the oldest publications, and “remote sensing” and “GIS data” with the most recent. However, the “remote sensing images” cluster is associated with the 2000–2015 period satellite missions (Landsat 5–7, MODIS, IKONOS, ALOS), and not to the most recent ones (e.g., Sentinel missions, except for id: 41). Satellite imagery and GIS data have been used to complete and contextualize some survey questionnaires in multi-sources studies, e.g., Google Earth images used for photo-interpretation (ids: 20, 57), normalized difference vegetation index (NDVI) index and urban characteristics (id: 50), or GIS data used to localize entomological observations (ids: 24, 58) or altitude associated with the mosquitoes’ environment (ids: 21, 34, 44, 64);
- By jointly using remote sensing and GIS data sources, some authors were able to describe both land use and land cover properties of the study area, e.g., vegetation index and urbanization level (id: 10), road network density and aging infrastructure (id: 14), bare soil detection and building type (id: 19), urban typology (“Urban Park”) and vegetation cover through NDVI index (id: 29), “urban village” and NDVI index (id: 51).

**Data sources network considering remote sensing images:** By mapping the structure of data from the “remote sensing images” source (Figure 5), we observe a strong structuring around the “land cover” properties of the landscape, mainly retrieved by the MODIS (500 m), ASTER (30 m), and Landsat 5 TM, 7 (30 m) moderate and high resolution sensors:

- “Land cover” is characterized by:
  - surface temperature (ids: 3, 42, 47, 76);
  - detection of buildings through the brightness index (id: 56);
vegetation cover through NDVI and VFC (ids: 3, 10, 29, 36, 42, 44, 45, 47, 51, 56, 69, 76, 78);
- water areas (ids: 14, 36, 41, 47, 56, 66, 67), and cropland (id: 36).

- “Building” is characterized by roof shape (id: 54), density (ids: 31, 41, 57, 69, 70), and surroundings based on density and distance from other land cover/use classes, e.g., vegetation (ids: 31, 56, 57, 67, 69, 70, 71), bare soil (ids: 19, 71), water-areas (ids: 56, 67, 71), cropland (ids: 36, 70), or road density (id: 36);
- “Land use” characterization is associated with high resolution sensors like Landsat 8 (30 m XS, id: 10) and ALOS (10 m XS, id: 57), and overall with very high resolution sensors like Ikonos (4 m XS, id: 19), Quickbird (2.4 mm XS, id: 10, 31, 69), WorldView 2 (0.46 m PAN, id: 54), Google Earth (Digital globe imagery, id: 20, 40) images, and Spot 5 (2.5 m PAN, id: 14, 32);
- “Land use” is thematically associated with “urban typology” and refers to the buildings function, e.g., residential, commercial, religious, industrial, or temporary construction (ids: 10, 19, 20, 57). Some authors define a local spatial index associated with the degree of urbanization and infrastructure of the area, e.g. the “percentage of urban villages” (ids: 10, 53), the percentage of “village area with vegetation” (id: 71), or the “quality of neighborhood” (id: 32).

Data sources network considering GIS: “GIS data” sources are initially collected from various sources such as digitised maps, geocoded census data, or in situ observations. The network shows a strong connection with the “land use” properties of the environment (Figure 5). Urban landscape is characterized through:
- “urban typology” associated with (i) urban morphology with construction height, e.g., “high or low-rise housing” (id: 58), (ii) building function, e.g., “tire repair shops” (id: 18) (ii) area functions, e.g., “residential/commercial/recreation” areas (ids: 19, 23, 57), “informal settlement” areas (id: 23, 51), “Park” (id: 29) “cemeteries” (id: 18);
- “infrastructure level”, e.g., proximity to the hospitals (id: 1), water network connection (ids: 15, 18, 23), canal and ditches (id: 15), “road density” or “parks area” (ids: 10, 18, 37, 50, 51);
- “housing type”, e.g., connections between houses. Some authors also considered topographic data, like shade or altitude, which influence the Aedes presence;
- GIS Land cover data indicates the presence of water areas and wetland (id: 16), and cropland (id: 16, 29);
- “Human presence” is characterized by geocoded density (id: 7);

Data sources network considering survey questionnaires: In the context of this mapping review, “survey questionnaires” associated with census data constitute the largest data sources for landscape characterization associated with dengue cases (Figure 6), and inform at household-level according to:
- housing type, with distinction between apartment, house, empty house, poor-condition house, old flat, sheds, shanty, villa with or without garden (ids: 2, 8, 13, 30, 38, 44, 48, 65, 74, 77), the number of storeys (ids: 26, 35, 46, 75, 77), and the construction material used to build the house: wood, stone, concrete, brick-wood, bamboo, or mixed material (ids: 4, 35, 55, 70, 71, 72, 73, 77);
- housing characteristics, by observing the presence/absence of: screens on the windows (ids: 4, 13, 26, 30, 35, 43, 65, 70, 73), shade in the patio (id: 30) house windows (id: 35), bednets (id: 71) air conditioning system (id: 9, 43), gutter rain water (id: 27), the connection to the water network or the presence of water containers (id: 8, 30, 43), the connection to a sewage system (ids: 8, 18, 68) or the collection of garbage and waste (ids: 8, 27, 30).

At an aggregate-level, for example, neighborhood or small-administrative level, survey questionnaires provide information about:
- land use through the characterization of (i) the urban typology, e.g., slum-like areas (ids: 3, 28, 65, 73), distinction between commercial, residential, landmarks (ids: 17, 35, 65, 74), neighbor
proximity (id: 26) (ii) the infrastructure level, often derived from “census data”, e.g., street drainage (ids: 9, 21, 65), water network (ids: 17, 59, 62), garbage collection (ids: 17, 65), public services availability (ids: 21, 61, 62, 63), and access to paved road (id: 38);

- some scarce information about the land cover in the surroundings: (i) the presence and characteristics of the vegetation, e.g., distance to “vegetation”, “tree height”, or “forested areas” (ids: 26, 63, 71, 73, 75) (ii) the presence of “bare soil” or cropland (id: 4);

- the topography of the urban site with the observation of the shade (ids: 26, 73), or the orientation of the street relative to the prevailing wind (id: 27);

- human density (ids: 17, 44, 61, 62, 74, 77), in some cases associated to some socio-economic characteristics (id: 63), human mobility (ids: 11, 77), or commuting patterns (ids: 28, 74).

Entomological observations are divided between:

1. direct mosquito observation at the different stages, through classical entomological (Breteau/house/container) index or self-defined index such as “number of females Aedes aegypti per person” (ids: 1, 4, 5, 6, 12, 24, 26, 28, 33, 34, 58, 59, 60, 68, 73);

2. breeding and resting sites, e.g., discarded container, uncovered water container, standing water in various recipients (ids: 9, 20, 25, 30, 34), or premises index (id: 61).
Figure 4. Keywords co-occurrences network associated to the 78 included articles, clustered by data sources (left), and year of publication (right). Nodes without labeling refer to landscape factors, which are detailed in the following network and sections. Nodes in italics refer to the type of the data acquisition sources.
Figure 5. Co-occurrences network mapping of the self-defined keywords related to the articles using remote sensing images (top) and Geographic Information System (GIS) (bottom) to produce the landscape factors.
Figure 6. Co-occurrence network mapping of the self-defined keywords related to the article using survey questionnaires to produce the landscape factors. We indicate in orange those factors that could also be produced through remote sensing techniques.
4. Dengue–Landscape Relationship Modeling

4.1. Proxies According to the Geographical Units of Spatial Analysis

Of the articles in this review, all the relationships between dengue occurrence and landscape features were based on aggregated data at a given geographic level. Relationships were not identified for individual dengue cases, except in id 22 (human mobility patterns of recently DENV-infected subjects). Since we considered data from survey questionnaires, a large number of relationships were identified at fine scale household-level, where the authors mainly considered the influence of house type and characteristics in the dengue transmission process, and exposure to *Aedes* bites by including entomological observations (ids: 1, 4, 8, 12, 13, 20, 25, 26, 34, 35, 48, 52, 55, 60, 68, 75, 77). Urban administrative divisions were often considered because (i) they represented the legal unit of dengue cases reports (ii) other datasets, such as demographic or socio-economic data, were aggregated and available at the same levels. Generally, the authors considered the smallest local administrative level, but we noticed a large diversity in the 78 articles in the names of organizations and the denomination of national administrative units: “Districts” (ids: 3, 32, 33, 36, 65), “Li” (id: 15), “BSA” (id: 16), Locality (id: 19), “Barrangay” (id: 23), “Cantones” (id: 44), “Municipios” (id: 62), “Colonies” (id: 63), “Villages” (id: 74), “health sectors” (ids: 27, 69) and “national census tracts” (ids: 11, 17, 38, 46). Five authors proposed a study considering the whole city (ids: 21, 41, 50, 64, 66) or very populated areas (id: 60). Various authors aggregated the data at the neighborhood level, considering dengue diffusion at fine scale linked with *Aedes* flight, or human density and proximity to *Aedes* presence (ids: 5, 6, 7, 9, 14, 18, 24, 28, 49, 54, 56, 57, 58, 59, 61, 67, 70, 71, 73, 78). According to individual authors justifications, we interpreted the choice of a landscape factor, considered at a given geographical unit of analysis, by its link to one or several mechanisms involved in the dengue transmission process (Table 4):

1. ecological factors favorable to *Aedes* presence and development through direct entomological observations, or elements of the landscape favoring the presence of breeding-resting sites;
2. probabilities of human exposure to *Aedes* bites at household-level through small-scale proxies associated to the housing type or its characteristics;
3. probabilities of human-vector encounter considered at neighborhood, small and large administrative levels;
4. virus conservation and diffusion through human mobility.
Table 4. Landscape factors interpreted as proxies of different processes involved in dengue transmission according to the geographical level of data aggregation.

| Landscape Factors | Proxies of | Geographic Level |
|-------------------|------------|------------------|
| **Housing characteristics:** Animal water pans, Households with water supply, regular water supply, water containers, sewage system, garbage collection | Aedes breeding or resting site | Household level |
| **Entomological observation:** Larvae-positive habitats, Breeding, discarded, infested discarded plastic containers, Discarded tire casings, Infested discarded cans, uncovered water containers | | |
| **Urban typology:** Slum-housing | | |
| **Land cover and use:** tree height | | |
| **Topography:** shade | | |
| **Housing characteristics:** Screens on windows, absence of air conditioning, Home with birds, house floors, Floor of principal living, Number of house windows, screens for house windows, yard/open space, shanty, Animals on the property, Living near open sewers, Bednets | Mosquito presence in the house, Breteau and house indexes | Exposure to Aedes bite |
| **Housing type:** Apartment, house, old flats, sheds, one storey homes | | |
| **Entomological observation:** Presence of adult Aedes albopictus and Ae. aegypti, Aedes aegypti and Ae. albopictus population density, % of houses with larva on the premises, Number of female Aedes aegypti per person, Mosquito presence in the house | | |
| **Urban typology:** Temporary construction, % of village area with vegetation | | |
| **Distance of house to vegetation, to river, Distance to waterbodies, % of bare soil in 200 m-buffer zone** | | |
| **Land cover land use:** Distance house to vegetation, to river, Distance to waterbodies, % of bare soil in 200 m-buffer | | |
| **Construction material:** Wood, concrete, stone and concrete construction | | |
| **Human Long-distance mobility** | Aedes Adults indicators | Human-virus mobility |
| **Human-virus mobility** | | |
| **Entomological observation:** Larvae abundance, Breteau Index, Premise index, Mosquito abundance, Aedes, Adults indicators | | |
| **Housing type:** Mean size of pitched and flatted roof. | Aedes presence, breeding or resting site | Neighborhood level |
| **Urban typology:** Slum housing | | |
| **Infrastructure level:** Density of the urban drainage network, Access to piped water | | |
| **Land cover land use:** Taro farming, Tasseled cap vegetation, wetness, brightness, vegetation coverage | | |
| **Housing type:** Multi-floor building, Single story attached and detached building | | |
| **Construction material:** Brick-made, wood houses | | |
| **Urban typology:** Dense populated areas surrounded by vegetation, Ratios on residential, industrial, commercial areas, slums-unplanned areas, Distances to neighboring houses % of developed land, distance to roads | Human-Aedes encounter | |
| **Land cover land use:** Distance from forested areas, % of vegetation, % of water areas, % of bare soil in 200 m-buffer | | |
Table 4. Cont.

| Landscape Factors                  | Proxies of                      | Geographic Level   |
|------------------------------------|---------------------------------|--------------------|
| **Infrastructure level:** Short distance from hospital. Human household density, Commercial activity with human movements | Human-virus mobility | Neighborhood level |
| **Housing characteristics:** Gutter rain | Aedes presence, breeding or resting site | Small administrative level |
| **Infrastructure level:** % of households with no piped water, without systematic or inefficient garbage collection | Aedes presence, breeding or resting site | Small administrative level |
| **Topography:** Street orientation to the wind | Aedes presence, breeding or resting site | Small administrative level |
| **Land cover:** NDVI, VFC, Water-body areas, Agriculture, Wetland, Urban heat islands, % of tree cover | Aedes presence, breeding or resting site | Small administrative level |
| **Housing characteristics:** Poor housing condition, houses without windows screens | Aedes presence, breeding or resting site | Small administrative level |
| **Housing type:** Independent, mixed, unoccupied houses | Aedes presence, breeding or resting site | Small administrative level |
| **Urban typology:** % of urban villages, of single and empty houses, of building, of slums. Ratios on residential, industrial, commercial areas, Informal, deprived or wealthy areas, house density, Markets place, Landmarks, Urbanisation level | Aedes presence, breeding or resting site | Large administrative level |
| **Land cover:** Open areas, Vacant ground | Aedes presence, breeding or resting site | Large administrative level |
| **Infrastructure level:** Human density, Road density, Use of public transportation | Aedes presence, breeding or resting site | Large administrative level |
| **Infrastructure level:** Drainage | Aedes presence, breeding or resting site | Large administrative level |
| **Land cover:** Urban heat islands, NDVI, % of shrubs, wet grassland, water area, paddy field | Aedes presence, breeding or resting site | Large administrative level |
| **Urban typology:** Quality of neighborhood, % of construction area | Aedes presence, breeding or resting site | Large administrative level |
| **Infrastructure level:** Public services availability | Aedes presence, breeding or resting site | Large administrative level |
4.2. Statistical Models

To quantify the relationships between urban landscape factors and dengue cases, the authors adopted methodologies based on statistical and spatial analysis fields, classically employed in spatial epidemiology or disease risks geography [38]. Correlation is commonly used to quantify the direction and strength of the relationship, through Pearson and Spearman (ranking) correlation coefficients (ids: 1, 24, 29, 31, 33, 42, 44, 53, 56, 60, 61, 62, 64, 65, 67, 69, 76). The odds ratio, which quantifies the strength of the association between two events is also often used (ids: 13, 20, 25, 26, 27, 34, 48, 68). Ecological regression analysis was used to estimate a relationship equation between “dengue cases” and one or more independent “landscape-based predictors” at a given area-level, underlying several assumptions on the data distribution and its associated errors, such as independence between observed cases. Assuming a Gaussian conditional distribution of the dependent variable in respect to the predictors, several studies considered simple, multiple, or generalized linear models (ids: 17, 45, 47, 62, 66). Based on a Bernoulli conditional distribution of the categorical outcome variable in respect to its predictors, most of the authors used logistic and multivariate logistic regression models to estimate the probabilities of a dengue infection (ids: 2, 9, 13, 18, 22, 26, 39, 41, 43, 49, 70, 71, 75, 77). To introduce non-linearity terms due to the spatial dependence of the predictors, some authors considered the generalized additive model (GAM) (ids: 6, 10, 28, 50, 51). To adapt the model to local contexts, some authors used the geographically weighted regression method (GWR), which takes non-stationary variables into consideration and models the local relationships between predictors and dengue cases (ids: 14, 17, 32, 53, 54). Two studies considered a generalized linear mixed model (GLMM, id: 8, 29), a model that, in addition to the fixed effect, includes a random effect for which the hypothesis of independence of observations is no longer assumed [36].

5. Qualitative Relationships between Landscape Factors and Dengue Cases

5.1. Mapping of Relationships at Household-Level

Except for the use of air conditioning, which could appear as a protective factor (ids: 52, 55), the housing characteristics considered in the included articles generally presented non–significant relationships with dengue cases (Figure 7): e.g., the number of windows in a house, the distinction between “public” or “private” multi-storey flats, floor of principal entry, the use of water containers, or the housing size. Screens on windows might appear to be a protective factor in some cases (ids: 26, 43, 55, 70, 73), but the association with dengue cases was also observed as statistically non–significant (ids: 4, 13, 20, 30, 65), and positively associated (id: 35), which might reveals the high density of Aedes or vector-borne disease in the area. No clear relationship was generally associated with construction materials: e.g., wood can appear as non–significant (ids: 26, 55), positively (ids: 70, 73) or negatively (id: 71) associated to dengue cases according to the study. Concrete, stone, or brick do not appear to be protective factors (ids: 55, 65, 70, 71, 78). Entomological observations are generally positively associated with the presence of dengue: direct Aedes observations of adults, pupae, larvae, or infested and discarded containers (id: 1, 25, 34, 60). Aedes aegypti is much more cited than Ae. albopictus in the included articles. In the domestic environment of a house, the presence of shaded and vegetated areas, and the lack of street drainage appear as exposure factors (ids: 26, 30).

5.2. Mapping of Relationships at Neighborhood Level

At the neighborhood level, it is possible to define an urban typology associated with an area, by considering the housing type and the building functions (Figure 8). This led the authors to propose various urban ecotypes, and to consider the residential, commercial, or social function of a construction, after taking into consideration transportation or ecological aspects like density of roads or vegetation. Despite the difficulty in comparing authors’ self-definitions, the mix of residential and highly frequented areas, associated with multi-scale human mobility (e.g., road network density, ids: 14, 37), with vegetation in the surrounding areas generally show the strongest associations to dengue...
occurrences (ids: 10, 14, 19, 28, 35, 37, 51, 57). Considered separately as individual proxies, urban functions are generally not significant (ids: 18, 35). Slum–like or informal settlement areas may be positively associated with the presence of dengue (ids: 14, 28, 51, 53, 73), but not systematically (ids: 3, 49). Well structured urban areas, defined by a “quality index”, may have protective effects (id: 32). The height of buildings could have an influence: low-rise buildings may be more exposed than high-rise buildings (ids: 49, 58). Few articles considered human density directly as a proxy at neighborhood level, and it appears non significant or positively related to dengue cases (ids: 7, 26, 35). Entomological observations are fewer than at household-level, and may show significant (e.g., with $Aedes$ house index) or non–significant relationships (e.g., with $Aedes$ eggs, larvae, and pupae abundance, or Breteau index, defined as the number of positive containers per 100 houses inspected).

5.3. Relationships at Administrative Units

The authors considered a small administrative level to integrate data from institutional sources at fine scale (Figures 9 and 10). A co-occurrence network shows some similarities with the neighborhood level, highlighting the role of human density through residential area mapping (ids: 16, 19), and the importance of mixed areas, characterized by coming and going of people with some hot spots or a context favorable to the persistence of $Aedes$: urban villages (id: 10), deprived areas with medium-high density (id: 38, 44, 63), residential areas with commercial and industrial areas (id: 23), or informal settlement areas (id: 23). With regard to infrastructure level, it is useful to consider waste management and the state of the sewage networks (ids: 15, 27, 65), as well as road structure and density (ids: 10). The orientation of a street, the presence of empty houses, or the use of gutter rain are urban characteristics that could play a role in maintaining $Aedes$ (id: 27, 74). Building height is also a variable of interest (id: 46). Some authors have information on human mobility, generally significantly associated with dengue cases, which highlights the usefulness of estimating human fluxes (ids: 11, 22, 77). Historical epidemiological data are scarce, but allow for the study of dengue urban patterns over time, and are especially significant when associated to DEN serotypes (id: 35). Entomological observations are not aggregated or available at the level of administrative units. The presence and density of the $Aedes$ mosquitoes are addressed through prior knowledge on vector bio-ecology and remotely-sensed environmental data: (i) the classical index NDVI is used as a proxy of the vegetation, and is positively associated to dengue cases in two of the three studies (ids: 10, 42, 50), (ii) urban surface temperature was not significant (id: 42). At larger administrative levels, authors considered the influence of altitude, which is negatively correlated to dengue occurrences (ids: 21, 34, 44, 64). This result illustrates the influence of the temperature gradient on $Aedes$ ecology. Human mobility is also correlated with dengue cases (id: 20, 22). Vegetation also seems positively associated with dengue occurrence (id: 36), although NDVI is associated with a negative relationship to dengue in two cases (id: 3, 45), which could be due to a decrease in residential surfaces in respect to vegetation surfaces.
Figure 7. Co-occurrences network mapping of the self-defined keywords related to the landscape factors considered at household-level.

Figure 8. Co-occurrences network mapping of the self-defined keywords related to the landscape factors considered at neighborhood-level.
Figure 9. Co-occurrences network mapping of the self-defined keywords related to the landscape factors considered at small administrative-level.

Figure 10. Co-occurrences network mapping of the self-defined keywords related to the landscape factors considered at large-administrative and city-level.
6. Discussion

6.1. Methodological Considerations

The expansion of evidence-based practice across scientific disciplines has led to an increasing variety of review types. We chose a mapping review, which enables the contextualization of in-depth systematic literature reviews within broader literature and identification of gaps in the evidence base [40]. The network, based on calculating the barycenter of the structured textual information, is aimed at proposing a coherent synthesis in a graphical way. The forms of the network graph are however quite dependent on the way information is sorted, structured and grouped. Our work is limited to a broad descriptive and qualitative level, and thus may oversimplify the considerable variations (heterogeneity) between studies and their findings [40]. Mapping reviews do not usually include a quality assessment process to preselect the articles, which could limit considerably the quality of the information and analyses produced. To provide an assessment of the risk of bias, we proposed here a simple checklist on key features based of metadata completeness, and an overall appraisal of the level of contributive information respect to the topic “dengue–relationship characterization” (Supplementary Materials). In addition, we did not include conference papers, which could contain some relevant information at the front-line of the research. We focused on urban areas, but rural areas could contribute at least as much to the dissemination of dengue fever as cities [56]. In a context of significant increase of dengue publications over time [57], our study highlights that specific research on spatial epidemiology, like dengue landscape factors, is not at the front line compared to virology, biochemistry or molecular biology research areas. Surprisingly, we did not find any articles which follow our inclusion criteria related to other Aedes-borne diseases, like Zika and Chikungunya when we swap dengue to one of them. These can be relativized by the recent character of the massive outbreaks associated to the Zika flavivirus [58,59]. We found only one study concerning Africa, which might be due to (i) many other competing public health problems (e.g., malaria or Ebola) and limited resources [60], which cause a lack of diagnostic testing and systematic surveillance [61] and (ii) a less suitable environment for dengue [62], with potential differences in terms of vector efficiency and viral infectivity between Africa and other dengue-endemic regions [63]. However, depending on location, rapidly increasing urbanisation, and/or higher temperatures and increased rainfall could increase dengue incidence in the following decades [62,63]. In general, only one article mentioned a given landscape factor, which prevented us from performing a more in depth meta-analysis, and limited us to the present qualitative analysis.

6.2. Potential limitations in Dengue-Landscape Studies

6.2.1. Limitations Associated with Epidemiological and Entomological Data

Through this review, we noted that passive notification cases, reported by official health systems, and dengue serostatus surveys, performed by research teams, can show two different realities of dengue occurrences, relativizing in this way the comparison between the factors proposed in the types of studies. Passive case notification datasets present strong identified biases due to (i) the absence of asymptomatic cases (ii) the absence of symptomatic cases when patients do not consult because of, particularly, the distance to health centers, or their cultural habits, and (iii) misdiagnose based on insufficient medical evidence. On the other hand, intra-urban dengue seroprevalence surveys are based on a sampling strategy where assumptions and representativeness may be inaccurate, and could limit interpretation: lack of demonstrable spatial variation between self-defined areas (id: 8), complexity to define an appropriate urban ecosystem (id: 35), relative influence of contextual indicators versus individuals (id: 48), and limitation to school children population (ids: 49, 67). Unknown socio-demographic drivers, the retrospective nature of questionnaires, and associated recall bias are other issues that should be mentioned (id: 49).
Four distinct serotypes of DENV have been identified, and infection from one serotype confers protective immunity against that serotype but not against other serotypes [64]. Acquired immunity may therefore introduce a bias in any dengue pattern study. From that perspective, historical studies of dengue epidemics can provide valuable information. However, such data are scarce, and few studies have performed both IgM and IgG analysis in the correct time window. Early tests (up to day 7) using Reverse Transcription Polymerase Chain Reaction (RT–PCR) should be preferred because their specificity is much higher than serology, but only one study has performed a Plaque Reduction and Neutral Test (PRNT) to distinguish between dengue serotypes (id: 36). In one study, two time–periods have been considered to distinguish potential infections by DENV-1 and DENV-2 (id: 16).

Underreporting in dengue surveillance systems has been identified in various studies [65–67] demonstrate, through a systematic review, that a large proportion of the data from any affected population has not been captured through passive routine reporting—misdiagnosis or subclinical cases, non-users of health services, users of private versus traditional sectors, or certain age groups. In high endemic settings, however, if the dengue cases are geographically representative and laboratory confirmed, dengue data may be representative, to some extent, and possibly corrected by calculating an expansion factor. Improvements in dengue reporting could come from improvement in indicators/alert signals, laboratory support, motivation strategies, shifts in dengue serotypes or genotype surveillance, and data forms/entry/electronic-based reporting [66].

Dengue cases were rarely associated with entomological data, probably due to the difficulty in obtaining these data in a cost-effective way. Except for household-level studies, mosquitoes were generally considered from prior knowledge, and not from in situ observations. Aedes were sometimes considered as composed of a unique species, without differentiating albopictus from aegypti despite their different ecological behaviours. This point could however be relativized because of the remarkable ecological plasticity of both species, especially to urban settings [10,11].

6.2.2. The Difficulty in Defining a Geographical Unit of Spatial Analysis

The first requirement in performing a relationship between dengue cases and environmental determinants is the geolocation of the cases. Most of the selected studies do not go into detail on that point, except when an automated procedure has been implemented (id: 42). Generally, a hypothesis is made after dengue cases have been located at a patient’s home address as the transmission may have occurred at home or in the vicinity of the household. Aedes aegypti and Ae. albopictus are day time biting mosquitoes, which implies to consider human commuting pattern. Such hypothesis might be strengthened when considering an age stratification, as the mobility of elderly persons or young children mobility can be limited for example (ids: 17, 70). If the dengue cases are located within a given area, the probability of the transmission may increase up to a threshold distance, but it might become more difficult to identify the correct environmental determinants associated with the transmission. These proximity-hypotheses are consistent with local, density dependent transmission as key sources of viral diversity, and with home location being the focal point of transmission [68]. Using geolocated genotype and serotype data, Salje et al. [68] showed that in Bangkok (Thailand), dengue cases came from the same transmission chain for (i) 60% of cases living in less that 200 meters apart, and (ii) 3% of cases separated by 1 to 5 kilometers. At distances closer to 200 meters from a case, the authors estimated the effective number of chains of transmission to be 1.7, and that this number rises by a factor of 7 for each 10-fold increase. As in the large majority of ecological-related issues ([69], Modifiable Area Unit Problem), the choice of an appropriate spatial unit to associate a relationship between dengue cases and their risk factors has a strong influence on effective analysis. We identified various type of infra-urban areas of spatial analysis in the 78 included articles (e.g., buffers around the infected households, census tracts, health regions, small and large administrative areas), which varied according to authors’ choices, data sources and availability. Dengue cases and landscape factors are often aggregated to an administrative level or census tracts to perform comparisons with socio-economic or demographic datasets. When considering an administrative area, there is a risk of disruption with
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6.3. Highlights and Perspectives to Improve the Frame of Urban Dengue-Landscape Relationships Studies

Our purpose was originally to identify studies based on remote sensing techniques to produce landscape factors, so we opened our search to all kinds of information sources, including survey questionnaire and GIS data. Such strategy is guided by the consideration of a holistic conceptual risk and vulnerability framework [71], to allow for the identification of new factors that would be potentially achievable by using remote sensing techniques. The main purpose was to identify what makes a given landscape “pathogenic” or not, in respect to dengue transmission [72]. We privileged a “Built City” approach, i.e. a city as a physical entity, [44], to avoid direct socio-economic considerations in landscape factors. Discursive links between dengue and poverty may have contributed to an inappropriate transfer of globally dominant dengue control strategies to non-poor local environment [73]. From this perspective, the quantification of human exposure to Aedes bites through salivary antibody-based biomarkers may be a promising method for estimating the influence of the bio-physical environment on human–Aedes contact [74]. Only two articles used landscape metrics to explore the impact of more in-depth ecological characteristics of an urban landscape on dengue transmission (ids: 57, 69). Landscape metrics have been separately applied to malaria transmission for assessing the influence of landscape factors relative to exposure risk [75,76]. The representativeness of sampling strategies during intra-urban dengue seroprevalence surveys may be improved by the use of GIS and remote sensing techniques ([77], e.g., urban environmental clustering and Aedes density); ([78], e.g., Urban typology) and help to objectify the choice of geographical units ([70], e.g., criteria of intra-unit homogeneity, areal and population size, compactness); ([71,79], e.g., Concept of integrated geons). Public health services could also benefit from original visualization techniques to map metrics or indexes related to dengue vectors or occurrences ([80], e.g., Ring mapping).

Id 22 highlighted the importance of human movement, and time spent in places at various scale in human exposition and DENV spreading. Id 37 showed that high-density road network is an important factor to the direction and scale of dengue epidemic, and that the dengue cases were mainly concentrated in the vicinity of narrow roads. Id 63 insisted on the “forest fire” signature of DENV epidemiology in the context of Dehli (India), while id 61 refers to a “silent epidemic in a complex urban area” in the context of Salvador (Brazil), where “high rates of transmission were observed in all studied areas, from the highest to the lowest socio-economic status.” Many authors referred to the necessity of an improvement in the individual geolocalisation capacity to estimate human mobility patterns, since an “importation of infected individuals into a frequented area could lead to a local foci of infection included with a low Aedes density”. Id 12 considered that “dengue transmission occurs, not at a fixed entomologic figure/quantity but rather at a variable level based on numerous factors including seroprevalence, mosquito density and climate.” Entomological indices may be good proxy of DENV occurrences at household-level (ids: 4, 34, 68, 75), but seem less significant when aggregated at coarser resolutions (ids: 6, 26, 28, 59), or when considering only larvae (id: 5). Some important data relative to vector borne diseases are exclusively accessible by field survey, e.g., type of material construction or screens on windows, but their knowledge do not seem so critical in the case of Aedes borne disease (ids: 4, 13, 70, 73). Many survey questionnaires based studies confirmed the large inadequacy of remote sensing techniques to properly identify potential dengue risk factors in link with Aedes habitats, characterized by a fine or micro-scale level: empty houses, sewage system, garbage system, street drainage, water pumps, water containers, open sewers, tyres, water puddle, ditches, cans (ids: 8, 9, 17, 18, 33, 65, 68, 74). However, remote sensing techniques should be now in capacity to provide more than land cover information, and could help to systematically inform on land use and
urban typology, without the need of a questionnaire, as (i) proxies of human presence and activity, or as (ii) macro-scale hotspot proxies of *Aedes* habitats e.g., cemeteries (id: 17), construction site (id: 36), vegetation height (ids: 26, 73), shade (ids: 26, 73), or roof shape (id: 54). Based on sound statistical machine learning, such complex urban typology could be labeled from space at neighborhood or small administrative level: informal settlement areas (ids: 23, 28, 49), urban villages (52), quality of neighborhood index (ids: 32, 52), or multiple association of urban functions (ids: 18, 19, 23, 35, 57), especially if completed by building height (ids: 58, 46, 75). Such improvement could help to explicit the multiscale geographical framework where DENV transmission occurs as a result of a multifactorial process. At the same time, remote sensing products could help to guide the questionnaire during the field survey, while GIS provide the framework to combine all spatialized information and performs geo-analysis (id: 10). Although remotely sensed radiometric measures like NDVI or LST could provide conflicting conclusions (ids: 3, 10, 42, 44, 50, 69), their use in a sound methodological framework could be of some interest, especially when available at higher resolutions. Digital archiving in GIS context of geocoded and confirmed dengue cases should help to easily inform on historical dengue risks areas (id: 35). Such digital layers could provide an interesting proxy of dengue transmission patterns when DENV-serotype is known.

As was apparent during this review, we were not able to identify a set of land cover and land use classes unequivocally related to dengue risk factors. This is consistent with the fact that reliable predictors for dengue have not yet been established in the literature [36], and the *Aedes* presence and density are not sufficient to determine dengue epidemics [13], which justifies the scope of this review, centering on dengue cases. DENV transmission is complex, and the relationship between vector density and risk is not static nor adequately characterized through periodic entomological surveillance [81]. However, even if *Aedes* indicators serve as surrogates of true exposure [81], vector control will remain the primary prevention strategy in most dengue endemic settings [1], including when an effective dengue virus (DENV) vaccine would become commercially available [18]. To better target surveillance programs, effective control of *Aedes* could benefit from available evidence-based guidance by considering an Integrated *Aedes* Management framework ([82,83], IAM).

Some specific factors are unachievable using remote sensing techniques due to their limited spatial dimension and should continue to be acquired by field and entomological surveys, e.g., decimetric spatial resolution for breeding sites or for gutter rain, or because they are hidden from the sensor perspective. However, building detection remains a central task as it allows human presence and density to be identified, and is constrained geographically to the urban area. Building environment, e.g., vegetation or water areas, is also of interest since it could influence *Aedes* ecology or human activities. Building function, e.g., residential or commercial, can give important information about human activities and human presence related to time. Road and transport networks may also constraint *Aedes* and DEN virus diffusion, and can be related to patterns of human commuting. Land use data related to human movement and places visit frequency should help in reducing the difficulty of acquiring detailed knowledge about “the non-random nature of encounters” [8]. In this way, urban mapping, particularly by including land use, could provide the geographical context in which, with adequate parameters that compensate for missing information, dengue-related processes could be modelled ([36], Review on modeling tools for dengue risk mapping; [84–86], Getis-Ord Gi in GIS context; [87–89], Spatial Mechanistic Modeling of *Aedes* Mosquito Vectors; [90], Spatial agent-based simulation model of the dengue vector *Aedes*; [91], Environmental hazard index mapping methodology of *Aedes* aegypti; [92], Modeling Dengue vector population using remotely sensed data and machine learning; [93], Comparison of stochastic and deterministic frameworks in dengue modelling).

To improve surveillance and monitor of dengue occurrences and *Aedes* mosquitoes, intercomparison model projects could help to identify the most general and efficient models considering various geographical contexts and data set: ([94], e.g., Airborne spread of foot-and-mouth disease – Model intercomparison; https://www.theia-land.fr/en/anisette-tracking-mosquitoes-that-carry-disease/, e.g., Inter-Site Analysis: Evaluation of Remote Sensing as a predictive tool for the
surveillance and control of diseases caused by mosquito, and future impacts of climate and/or land use changes may also be considered; [95], e.g., Malaria and climate; [17,23,96], e.g., Urbanization). Review of literature are also needed to update the ever-increasing output of scientific publications, and lead to new synthetic insights ([97]; [10], e.g., Determinants of Aedes Mosquito Habitat for Risk Mapping, [98], e.g., New frontiers for environmental epidemiology in a changing world, [99], e.g., Current challenges for dengue; [100], e.g., Mosquito-Borne Diseases: Advances in Modelling Climate-Change Impacts; [101], e.g., A 10 years view of scientific literature on Aedes aegypti; [102], e.g., Satellite Earth Observation Data in Epidemiological Modeling).

The potential of satellite images and remote sensing techniques should continue to be explored. As mentioned in this review, the images used often corresponded to old missions or end-of-life satellite sensors, and methodologies should consider more state-of-the-art-approaches:

- the native pixel resolutions were often aggregated at a coarser resolution during the mapping production (Figure 11). Recent satellite missions should bring greater possibilities to fit spatial resolution and temporal windows over urban areas, for example the Copernicus Sentinel program ([103], Monitoring Urban Areas with Sentinel-2A Data), or on demand very high-resolution sensors ([104], Pléiades satellite potential for urban tree mapping);
- image processing was previously limited to spectral indices (NDVI, VFC), or some supervised pixel-based classifications mostly based on the maximum likelihood algorithm (ids: 57, 69, 70, 71). Only one study considered object-based classification for building extraction purposes (id: 77). Such approaches could benefit from methodological advances, especially from the urban mapping community—([105], Comparison of Deep Neural Networks, Ensemble Classifiers, and Support Vector Machine Algorithms) ([106], “Compared with the traditional rule-based and ML [Machine Learning] methods, the DL [Deep learning]-based classification method has significant advantages in terms of classification accuracy, especially in complex urban areas”) ([47], Google Earth Engine Platform), ([107], VHR and landscape-structure heterogeneity), ([108], Urban change detection), ([109], Street-level imageries) ([110], VHR images and slums detection);
- two studies have exploited the thermal sensors from Landsat-TM and MODIS instruments, and used them to retrieve land surface temperature (LST) parameters (ids: 3, 19). This is particularly useful to detect urban heat islands that could indicate improved conditions for Aedes viability and dengue virus replication, due to the potentially amplified higher temperatures (typically greater than 30°C), and resulting in a reduction of the extrinsic incubation period from 12–14 days to 7 days ([111], id: 3). New thermal sensors with higher spatial resolution may promote consideration of thermal sensors, such as the CNES-TRISHNA mission [112,113], even if methodological issues remain: that is, hotspot effects, separation of temperature and emissivity parameter.
- dengue is often spread in tropical or subtropical regions, where the presence of clouds and cloud shadows result in missing data in optical images. Synthetic aperture radar SAR images could penetrate such barriers and might be combined with optical sensors for overcoming this issue. Such an approach to optical and SAR fusion has been applied in the studies of malaria [114,115];
- very high resolution imagery may be more suitable for extracting the direct dengue-related landscape factors, such as (i) the type of vegetation near human settlements [104,116] (ii) the footprint of built-up areas [46,117], and (iii) land use types, such as slum areas [118,119];
- from high-resolution built-up area detection, population growth estimation due to urbanization could be assessed, improving the estimation of census and incidence rates [120,121]. In this regard, only one article proposed a proxy for a spatially-corrected population density by digitizing and excluding inhabited areas (id: 24). To improve the population density assessment, cities should be considered in their verticality and volume, through the use of a digital height model, potentially generated from unmanned or satellite remote sensing stereo imagery [122–124];
although we did not consider meteorological factors here, surface air temperature or soil moisture, traditionally measured by in situ weather stations, could be derived from satellite passive microwave radiometry [102,125].

The temporal dimension remains largely absent in the spatio-temporal relationship studies of this review. Populations commute, as well as mosquitoes. If a decrease in mean distance between dengue cases may generally correlates with activity, and could lead up to an outbreak, a decrease in temporal distance between dengue cases may increase geographic spread of the disease [126]. Landscape changes associated with human mobility, like transportation infrastructure changes, may create favorable conditions for the establishment of dengue virus [127]. However, relationship investigations are usually done under a stationary analysis scheme, and the mapping of dengue patterns often ignore “temporal kinetics” (id: 32). A complementary approach to this static view should be to consider human mobility in relation to Aedes-bites exposure, and not only to mosquito dispersal associated with its flight, as this former could affect significantly the spread of infection [128]. Adams and Kapan [129] enhanced the fact that hubs and reservoirs of dengue infection can be places people visit frequently but briefly. Authors from id 74 found that most of the space-time distances of non-commuting dengue cases clustered within 100 m and one week, whereas commuting cases clustered within 2 to 4 km and one to five weeks. Human commuting patterns may be estimated through the use of GPS data-logger (id: 22) [130] or regularly logged cellphone tracking data [131], which could be in the next decade generalized in the so-called Smart City model ([132] Real Time Health Monitoring, [133] Smart Health care Internet of Things and Aedes monitoring, [134] Geospatial artificial intelligence).

**Figure 11.** Comparison between pixel size (x axis, in log scale) and typical dimension of geographical area used to perform relationships with dengue cases (Y axis, in qualitative dimension).

7. Conclusions

We propose here a mapping review which focuses on the landscape factors potentially related to urban dengue transmission. By analysing the 78 included articles that satisfied these criteria, we found that the landscape mapping linked to human dengue infection was mainly guided by (i) vector ecology-based considerations through vegetation and water surface mapping and (ii) human presence and activities deducted from the settlement typology.

We extracted each of the specific landscape features that have been assessed in the context of DENV transmission. We proposed a systematic three-valued interpretation of the relationships
performed between each landscape factors and dengue occurrences, and provided a representation in a graphical way according to the considered spatial scale of the studies. Even if some characteristics appear essential, as human density and movement pattern, or the presence of a minimum vegetation in the surrounding, considering only one landscape factor at a time should be avoided, as we highlighted the complexity of the “pathogenic landscape” associated to dengue transmission. In a broad and simplified approach, relevant landscape is characterized by a mix of residential and highly frequented areas, associated to multi-scale human mobility, with an entomological thresholds that can be low. From a remote sensing perspective, there is a need to identify land uses more than solely land covers to characterize more complex urban environment: informal settlement, building typology, transportation network, and consider the vertical dimension of the city. Up to now, these kinds of information have been more often retrieved from costly and time-consuming survey questionnaires than from automatic remotely-sensed approaches. To provide a realistic geographical context in dengue modelling and to take into account the complexity and the multi-factorial nature of DENV transmission in tropical environments, remote sensing approaches need to be promoted through the use of recent HR and VHR sensors such as, Copernicus (Sentinel) or Orfeo (Pleiades) programs, a combination of optical, including stereo, and RADAR approaches, and state-of-the-art image processing algorithms, including deep learning techniques when possible. A strengthening of relations between environmental epidemiology and urban mapping communities should help to standardize the mapping of the urban typology of interest, and therefore enable better assessment of the influence on dengue transmission.

As an integrated approach combining remote sensing, GIS, and field survey preferable when possible, since health data and entomological observation availability and quality would probably remain the main limiting factors if landscape and urban typology mapping, including human movement pattern, continue to improve. Due to the silent characteristics of DENV presence within the city, dengue control still requires above all an active search and an early detection of new cases, including serotype detection, associated to an entomological control at fine scale involving both citizen and health agencies.

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### Table A1. Extraction of the publication meta-data (first author, date of publication, title, name of the journal), and description of the geographical contexts (country, city, geographical unit) of the 78 included studies.

| ID [Ref.] | First Author | Date | Title | Journal | Country | City | Geographic Units of Spatial Analysis |
|-----------|--------------|------|-------|---------|---------|------|-------------------------------------|
| 1 [135]   | Ali          | 2003 | Use of a geographic information system for defininThe American journal of tropical medicine and hygiene | Bangladesh | Dhaka | 8820 Households (within 90 wards) |
| 2 [136]   | Al-Raddadi   | 2019 | Seroprevalence of dengue fever and the associated | Acta Tropica | Saudi Arabia | 4 cities, Makkah, Al Madinah, Jeddah, and Jizan | 6397 Households |
| 3 [137]   | Araujo       | 2015 | Sao Paulo urban heat islands have a higher incidence of dengue than other urban areas | The Brazilian Journal of Infectious Diseases | Brazil | Sao Paulo | Districts |
| 4 [138]   | Ashford      | 2003 | Outbreak of dengue fever in Palau, western pacific risk factors for infection | The American Journal of Tropical Medicine and Hygiene | Palau | 5 hamlets of Palau | (270) Households |
|           |              |      |       |         |         |      | Koror and five hamlets of Palau | (189 of 865) Households |
| 5 [139]   | Barbosa      | 2010 | Spatial Distribution of the Risk of Dengue and the Entomological Indicators in Sumaré, State of Sao Paulo, Brazil | Revista da Sociedade Brasileira de Medicina Tropical | Brazil | Tupa | Neighborhoods |
| 6 [140]   | Barbosa      | 2014 | Spatial Distribution of the Risk of Dengue and the Entomological Indicators in Sumaré, State of Sao Paulo, Brazil | PLOS Neglected Tropical Diseases | Brazil | Sumare Sao Paulo state | Neighborhoods |
| 7 [141]   | Barrera      | 2000 | Estratificación de una ciudad hiperendémica en dengue hemorrágico | Revista Panamericana de Salud Pública | Venezuela | Maraquay | (349) Neighborhoods |
| 8 [142]   | Braga        | 2010 | Seroprevalence and risk factors for dengue infection in socio-economically distinct areas of Recife, Brazil | Acta Tropica | Brazil | Recife | Households |
| 9 [143]   | Brunkard     | 2007 | Dengue Fever Seroprevalence and Risk Factors, Texas–Mexico Border, 2004 | Emerging Infectious Diseases | USA | Brownsville, Texas | (300) Households |
|           |              |      |       |         |         |       | Matamoros, Tamaulipas | Neighborhoods |
| 10 [144]  | Cao          | 2017 | Individual and Interactive Effects of Socio-Ecological Factors on Dengue Fever at Fine Spatial Scale: A Geographical Detector-Based Analysis | International Journal of Environmental Research and Public Health | China | Guangzhou | (167) Townships-streets |
### Table A1. Cont.

| ID [Ref.] | First Author | Date | Title                                                                 | Journal                                                                 | Country | City          | Geographic Units of Spatial Analysis |
|-----------|--------------|------|----------------------------------------------------------------------|------------------------------------------------------------------------|---------|---------------|--------------------------------------|
| 11 [145]  | Carbajo      | 2018 | The largest dengue outbreak in Argentina and spatial analyses of dengue cases in relation to a control program in a district with sylvan and urban environments | Asian Pacific Journal of Tropical Medicine                               | Argentina | Tigre            | Census tracts                        |
| 12 [146]  | Chadee       | 2009 | Dengue cases and Aedes aegypti indices in Trinidad                   | Acta Tropica                                                            | Trinidad | County Victoria | (50) Households                     |
| 13 [147]  | Chen         | 2016 | Who Is Vulnerable to Dengue Fever? A Community Survey of the 2014 Outbreak in Guangzhou, China | International Journal of Environmental Research and Public Health         | China    | Guangzhou      | Households                           |
| 14 [148]  | Chen         | 2019 | Spatiotemporal Transmission Patterns and Determinants of dengue fever: a case study of Guangzhou, China | International Journal of Environmental Research and Public Health         | China    | Guangzhou city | Grid-level 1km                       |
| 15 [149]  | Chiu         | 2014 | A Probabilistic Spatial Dengue Fever Risk Assessment by a Threshold-Based-Quantile Regression Method | PLoS ONE                                                                 | China    | Kaohsiung Fongshan | Li (Smallest Administrative Unit)    |
| 16 [150]  | Chuang       | 2018 | Epidemiological Characteristics and Space-Time Analysis of the 2015 Dengue Outbreak in the Metropolitan Region of Tainan City, Taiwan | International Journal of Environmental Research and Public Health         | China    | Tainnan         | BSA, village (Small Administrative newline Unit) |
| 17 [151]  | Delmelle     | 2016 | A spatial model of socioeconomic and environmental determinants of dengue fever in Cali, Colombia | Acta Tropica                                                            | Colombia | Cali            | (323) Neighborhoods                  |
| 18 [152]  | De Mattos     | 2007 | Spatial Vulnerability to Dengue in a Brazilian Urban Area During a 7-Year Surveillance | Journal of Urban Health                                                   | Brazil   | Belo Horizonte | (254) census tracts                  |
| 19 [153]  | Dom          | 2013 | Coupling of remote sensing data and environmental-related parameters for dengue transmission risk assessment in Subang Jaya, Malaysia | Geocarto International                                                   | Malaysia | Subang Jaya    | Locality (Small Administrative Unit) |
| 20 [154]  | Ellis        | 2015 | A Household Serosurvey to Estimate the Magnitude of a Dengue Outbreak in Mombasa, Kenya, 2013 | PLOS Neglected Tropical Diseases                                         | Kenya    | Mombasa         | (701) Households                     |
### Table A1. Cont.

| ID [Ref.] | First Author | Date | Title                                                                 | Journal                                           | Country     | City          | Geographic Units of Spatial Analysis |
|-----------|--------------|------|----------------------------------------------------------------------|---------------------------------------------------|-------------|---------------|-------------------------------------|
| 21 [155]  | Escobar-Mesa | 2003 | Determinantes de la transmisión de dengue en Veracruz: un abordaje ecológico para su control | Salud Pública de México                            | Mexico      | Veracruz      | (1249) Localities                   |
| 22 [156]  | Falcon-Lezama| 2017 | Analysis of spatial mobility in subjects from a Dengue endemic urban locality in Morelos State, Mexico | PloS one                                           | Mexico      | Axochiapan city | Trajectory in and out of the city  |
| 23 [157]  | Garcia       | 2011 | An examination of the spatial factors of dengue cases in Quezon City, Philippines A Geographic Information-System GLS based approach 2005-2008 | Acta Medica Philippina                             | Philippines | Quezon         | Barrangay (Small Administrative Unit) |
| 24 [158]  | Hapuarachchi | 2016 | Epidemic resurgence of dengue fever in Singapore in 2013-2014: A virological and entomological perspective | BMC Infectious Diseases                            | Singapore   | Singapore      | 150 m buffer around clustered cases |
| 25 [159]  | Hayes        | 2003 | Risk factors for infection during a severe dengue outbreak in el Salvador in 2000 | The American Journal of Tropical Medicine and Hygiene | Salvador    | Aguilares (Las Pampitas) | (106) Households |
| 26 [160]  | Hayes        | 2006 | Risk factors for infection during a dengue-1 outbreak in Maui, Hawaii, 2001 | Transactions of The Royal Society of Tropical Medicine and Hygiene | USAHawaii | Nahiku Hana | Households                          |
| 27 [161]  | Heukelbach   | 2001 | Risk factors associated with an outbreak of dengue fever in a favela in Fortaleza, north-east Brazil | Tropical Medicine & International Health           | Brazil      | Fortaleza Favela Serviluz | Self-defined districts |
| 28 [162]  | Honorio      | 2009 | Spatial Evaluation and Modeling of Dengue Seroprevalence and Vector Density in Rio de Janeiro, Brazil | PLoS Neglected Tropical Diseases                  | Brazil      | Rio de Janeiro | (3) Neighborhoods |
| 29 [163]  | Huang        | 2018 | Spatial Clustering of Dengue Fever Incidence and Incidence and its association with surrounding greenness | International Journal of Environmental Research and Public Health | China      | Tainan Kaohsiung | Districts                          |
| 30 [164]  | Kennesson    | 2019 | Social-ecological factors and preventive actions decrease the risk of dengue infection | PLOS Neglected Tropical Diseases                  | Ecuador     | Machala       | Households                          |
| ID  | First Author | Date  | Title                                                                 | Journal                                                        | Country    | City                  | Geographic Units of Spatial Analysis |
|-----|--------------|-------|----------------------------------------------------------------------|---------------------------------------------------------------|------------|-----------------------|-------------------------------------|
| 31  | Kesetyaningsi | 2018  | Determination of environmental factors affecting dengue incidence in Sleman District | African Journal of Infectious Diseases                        | Indonesia  | Sleman District       | 200 m buffer                        |
| 32  | Khormi        | 2011  | Modeling dengue fever risk based on socioeconomic parameters, nationality and age groups: GIS and remote sensing based case study | Science of The Total Environment                               | Saudi Arabia | Jeddah                | (111) Districts                     |
| 33  | Kim          | 2015  | Role of Aedes aegypti and Aedes albopictus during the 2011 dengue fever epidemics in Hanoi, Vietnam | Asian Pacific Journal of Tropical Medicine                    | Vietnam    | Hanoi                 | (8) Districts (1200) 50 m-buffers around Households |
| 34  | Koopman      | 1991  | Determinants and Predictors of Dengue Infection in Mexico             | American Journal of Epidemiology                               | Mexico     |                        | (3408) Households                   |
| 35  | Koyadun      | 2012  | Ecologic and Sociodemographic Risk Determinants for Dengue Transmission in Urban Areas in Thailand | Interdisciplinary Perspectives on Infectious Diseases          | Thailand   | Chachoengsao’s province cities | (1200) Households considering (4) ecotypes |
| 36  | Li           | 2013  | Abiotic Determinants to the Spatial Dynamics of Dengue Fever in Guangzhou | Asia Pacific Journal of Public Health                         | China      | Guangzhou             | (12) Districts                      |
| 37  | Li           | 2018  | Spatiotemporal responses of dengue fever transmission to the road network in an urban area | Acta Tropica                                                  | China      | Guangzhou             | 500 m distance from roads           |
| 38  | Lippi        | 2018  | The social and spatial ecology of dengue presence and burden during an outbreak in Guayaquil, Ecuador, 2012 | International Journal of Environmental Research and Public Health | Ecuador    | Guayaquil             | Census tract                        |
| 39  | Liu          | 2018  | Dynamic spatiotemporal analysis of indigenous dengue fever at street-level in Guangzhou city, China | PLOS Neglected Tropical Diseases                               | China      | Guangzhou             | Street-level                        |
| 40  | Mahmood      | 2019  | Spatiotemporal analysis of dengue outbreaks in Samanabad town, Lahore metropolitan area, using geospatial techniques | Environmental Monitoring and Assessment                        | Pakistan   | Samanabad             | Union Council                       |
| ID [Ref.] | First Author | Date | Title | Journal | Country | City | Geographic Units of Spatial Analysis |
|-----------|--------------|------|-------|---------|---------|------|------------------------------------|
| 41 [175]  | Mala         | 2019 | Implications of meteorological and physiographical parameters on dengue fever occurrences in Delhi | Science of The Total Environment | India | Delhi city | City |
| 42 [176]  | Martinez     | 2017 | Relative risk estimation of dengue disease at small spatial scale | International Journal of Health Geographics | Colombia | Bucaramanga | (293) Census tracts |
| 43 [177]  | McBride      | 1998 | Determinants of dengue 2 infection among residents of Charters Towers, Queensland, Australia | American journal of epidemiology | Australia | Charters Towers | 1000 Households |
| 44 [178]  | Mena         | 2011 | Factores asociados con la incidencia de dengue en Costa Rica | Revista Panamericana de Salud Pública | Costa Rica | Various cities | (81) Cantones |
| 45 [179]  | Meza-Ballesta| 2014 | The influence of climate and vegetation cover on the occurrence of dengue cases (2003-2010) | Revista de Salud Pública | Colombia | Various cities | (30) Municipios |
| 46 [180]  | Mondini      | 2008 | Spatial correlation of incidence of dengue with socioeconomic, demographic and environmental variables in a Brazilian city | Science of The Total Environment | Brazil | Sao Jose do Rio Preto | Census tract |
| 47 [181]  | Ogashawara   | 2019 | Spatial-Temporal Assessment of Environmental Factors related to dengue outbreaks in Sao Paulo, Brazil | GeoHealth | Brazil | Sao Paulo | District-level |
| 48 [182]  | Pessanha     | 2010 | Dengue em três distritos sanitários de Belo Horizonte, Brasil: inquérito soroprevalênciço de base populacional, 2006 a 2007 | Revista Panamericana de Salud Pública | Brazil | Belo Horizonte | Households |
| 49 [183]  | Prayitno     | 2017 | Dengue seroprevalence and force of primary infection in a representative population of urban dwelling Indonesian children | PLOS Neglected Tropical Diseases | Indonesia | 26 cities | Neighborhoods |
| 50 [184]  | Qi           | 2015 | The Effects of Socioeconomic and Environmental Factors on the Incidence of Dengue Fever in the Pearl River Delta, China, 2013 | PLoS neglected tropical diseases | China | 7 mains cities of Pearl River Delta, Guangdong | (402) streets and towns |
Table A1. Cont.

| ID [Ref.] | First Author | Date | Title                                                                 | Journal                                      | Country        | City                        | Geographic Units of Spatial Analysis |
|-----------|--------------|------|----------------------------------------------------------------------|----------------------------------------------|----------------|-----------------------------|-------------------------------------|
| 51 [185]  | Qu           | 2018 | Effects of socio-economic and environmental factor                     | Geospatial Health                            | China          | Guangzhou city              | Township-level                      |
| 52 [186]  | Reiter       | 2003 | Texas Lifestyle Limits Transmission of Dengue Virus                   | Emerging Infectious Diseases                 | USA-Mexico     | Laredo, Nuevo Laredo, Taumalipas | (622) Households                   |
| 53 [187]  | Ren          | 2019 | Urban villages as transfer stations for dengue fever epidemic: a case study in the Guangzhou, China | Emerging Infectious Diseases                 | China          | Guangzhou city              | 1 km square grid                   |
| 54 [188]  | Rinawan      | 2015 | Pitch and Flat Roof Factors' Association with Spatiotemporal Patterns of Dengue Disease Analysed Using Pan-Sharpened Worldview 2 Imagery | ISPRS International Journal of Geo-Information | Indonesia      | Bandung                      | Buffer 50 m                        |
| 55 [189]  | Rodriguez    | 1995 | Risk Factors for Dengue Infection during an Outbreak in Yanes, Puerto Rico in 1991 | The American Journal of Tropical Medicine and Hygiene | Puerto Rico    | Yanes (Florida)             | 65 households                      |
| 56 [190]  | Rotela       | 2007 | Space–time analysis of the dengue spreading dynamics in the 2004 Tartagal outbreak, Northern Argentina | Acta Tropica                                 | Argentina      | Tartagal                    | Residential block addresses         |
| 57 [191]  | Sarfraz      | 2014 | Near real-time characterisation of urban environments: a holistic approach for monitoring dengue fever risk areas | International Journal of Digital Earth       | Thailand       | Muang                       | Buffer 200 m                       |
| 58 [192]  | Seidahmed    | 2018 | Patterns of Urban Housing Shape Dengue Distribution in Singapore at Neighborhood and Country Scales | GeoHealth                                    | Singapore       | Singapore Geiyang           | 200 m-grid                          |
|           |              |      |                                                                      |                                               |                |                             | 1 km-block                          |
| 59 [193]  | Stewart-Ibarra| 2014| Spatiotemporal clustering, climate periodicity, and social-ecological risk factors for dengue during an outbreak in Machala, Ecuador, in 2010 | BMC Infectious Diseases                      | Ecuador        | Machala                     | (253) Neighborhoods                 |
| 60 [194]  | Sulaiman     | 1996 | Relationship between Breteau and house indices and cases of dengue/dengue hemorrhagic fever in Kuala Lumpur, Malaysia | Journal of the American Mosquito Control Association | Malaysia       | Kuala Lumpur                | 6 zones of 1 million inhabitants    |
| ID [Ref.] | First Author | Date | Title | Journal | Country | City | Geographic Units of Spatial Analysis |
|-----------|--------------|------|-------|---------|---------|------|--------------------------------------|
| 61 [195] | Teixeira     | 2002 | Dynamics of dengue virus circulation: a silent epidemic in a complex urban area | Tropical Medicine & International Health | Brazil | Salvador | (30) Neighborhoods |
| 62 [196] | Teixeira     | 2008 | Socio-demographic factors and the dengue fever epidemic in 2002 in the State of Rio de Janeiro, Brazil | Cadernos de Saúde Pública | Brazil | Rio state | (90) Municipios |
| 63 [197] | Telle        | 2016 | The Spread of Dengue in an Endemic Urban Milieu–The Case of Delhi, India | PLOS ONE | India | Dehli | (1280) Colonies |
| 64 [198] | Teurlai      | 2015 | Socio-economic and Climate Factors Associated with Dengue Fever Spatial Heterogeneity: A Worked Example in New Caledonia | PLOS Neglected Tropical Diseases | New Caled. | Various cities | City |
| 65 [199] | Thammapol    | 2008 | Environmental factors and incidence of dengue fever and dengue haemorrhagic fever in an urban area, Southern Thailand | Epidemiology and Infection | Thailand | Songkhla | Enumeration district |
| 66 [200] | Tian         | 2016 | Surface water areas significantly impacted 2014 dengue outbreaks in Guangzhou, China | Environmental Research | China | Guangzhou | City |
| 67 [201] | Tiong        | 2015 | Evaluation of land cover and prevalence of dengue in Malaysia | Tropical Biomedicine | Malaysia | 15 cities | Buffer 10 m |
| 68 [202] | Toan         | 2014 | Risk factors associated with an outbreak of dengue fever/dengue haemorrhagic fever in Hanoi, Vietnam | Epidemiology & Infection | Vietnam | Hanoi | (73) Households |
| 69 [203] | Troyo        | 2009 | Urban structure and dengue incidence in Puntarenas, Costa Rica | Singapore Journal of Tropical Geography | Costa Rica | PUNA-RENAS | Health region |
| 70 [204] | Van Benthem  | 2005 | Spatial patterns of and risk factors for seropositivity for dengue infection | The American journal of tropical medicine and hygiene | Thailand | (Ban Pa Nai Ban Pang Mae Ha) | Buffer 200 m |
| ID [Ref.] | First Author | Date | Title | Journal | Country | City | Geographic Units of Spatial Analysis |
|-----------|--------------|------|-------|---------|---------|------|-------------------------------------|
| 71 [205] | Vanwambeke  | 2006 | Multi-level analyses of spatial and temporal determinants for dengue infection | International Journal of Health Geographics | Thailand | (Ban Pa Nai Ban Fang) Mae Hia | Buffer 200 m |
| 72 [206] | Wanti        | 2019 | Dengue Hemorrhagic Fever and House Conditions in Kupang City, East Nusa Tenggara Province | Kesmas: National Public Health Journal | Indonesia | Kupang | Households |
| 73 [207] | Waterman     | 1985 | Dengue Transmission in Two Puerto Rican Communities in 1982 | The American Journal of Tropical Medicine and Hygiene | Puerto Rico | Manati Salinas communities | (60) blocks of 6 households |
| 74 [208] | Wen          | 2012 | Population Movement and Vector-Borne Disease Transmission: Differentiating Spatial—Temporal Diffusion Patterns of Commuting and Noncommuting Dengue Cases | Annals of the Association of American Geographers | China | Tainan city | 266 “Villages” (smallest administrative division) |
| 75 [209] | Wong         | 2014 | Community Knowledge, Health Beliefs, Practices and Experiences Related to Dengue Fever and Its Association with IgG Seropositivity | PLOS Neglected Tropical Diseases | Malaysia | Various cities | 1400 Households at 3 km of the schools |
| 76 [210] | Yue          | 2018 | Spatial analysis of dengue fever and exploration of its environmental and socio-economic risk factors using ordinary least squares | International Journal of Infectious Diseases | China | Guangzhou city | 1 km square Grid |
| 77 [211] | Yung         | 2016 | Epidemiological risk factors for adult dengue in Singapore: an 8-year nested test negative case control study | BMC Infectious Diseases | Singapore | Singapore | Households |
| 78 [212] | Zellweger    | 2017 | Socioeconomic and environmental determinants of dengue transmission in an urban setting: An ecological study in Nourméa, New Caledonia | PLOS Neglected Tropical Diseases | New Caledonia | Noumea | (36) Neighborhoods |
### Table A2. Epidemiological Characteristics and Vectors Mention (M) or Observation (O) in the 58 Included Articles

Data extracted from the 78 articles on the epidemiological context (time-span of the outbreak or of the serosurvey, data provider, method used to identify dengue virus, number of cases ([n]) or incidence (I) or prevalence (P), spatial distribution of the dengue occurrences). In last column, we indicate if vectors are only mentioned (M) or observed (O) in the study.

| ID [Ref.] | Start–End Years | DATA Source | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------|-----------|----------------|------------------|-----------------|
| 1 [135]   | 2000            | Self-reported dengue cases | NA | NA | NA | Clustered in the southern part (hospitals location) | Aedes aegypti and Aedes Albopictus (O) |
| 2 [136]   | Sep 2016-Jan 2017 | Sero-prevalence survey | IgG (ELISA) | NA | % by city | NA | Mosquitoes (M) |
| 3 [137]   | 2010–2011       | Passive notification (COVISA) | IgG (ELISA) | NA | N=7415 | Heterogeneous | Aedes aegypti (M) |
| 4 [138]   | 1995            | Passive notification (Palau Hospital) | Clinical and IgM and IgG | NA | N = 254 | Heterogeneous | Aedes aegypti albopictus, and hensilli (O) |
|           | Jan–Jun 1995    | Passive notification (PHD) and cross-survey | IgM (ELISA) and Virus isolation | N = 817 | P = 75% | | |
| 5 [139]   | Jan–2004–Dec–2007 | Passive notification (PCD) | Clinical and Lab. confirmed | NA | I = 281 per 100,000 | NA | Aedes aegypti (O) |
| 6 [140]   | Jan–Sep–2011    | Passive notification (SINAN) | Clinical and Lab. confirmed | DENV-1 DENV-2 DENV-3 | N = 195 | Heterogeneous | Aedes aegypti (O) |
| 7 [141]   | 1993–1998       | Sero-incidence | Clinical signs | NA | N = 10,576 N = 2593 (DHF) N = 8 (Death) | Observed Patterns | Aedes aegypti (M) |
| 8 [142]   | 2005–2006       | Sero-prevalence survey | IgG (ELISA) | NA | P = 91% P = 87% P = 74% | Socio-eco stratified | Aedes aegypti (M) |
| 9 [143]   | Oct–Nov 2004    | Sero-prevalence survey | Double IgM-IgG (ELISA), and PRNT | DENV-2 DENV-1 | N = 6 (Recent), N = 119 (Past) N = 22 (Recent), and N = 235 (Past) | NA | Aedes aegypti, albopictus, Culex quinque, fasciatus (O) |
| 10 [144]  | 2014            | Passive notification (CDCP) | Clinical, IgM, and PCR | NA | N = 37,322 | 4 clusters 1 Hotspot 3 cold spots (Moran’s I) | Aedes albopictus (aegypti) (M) |
| ID [Ref.] | Start–End Years | DATA Source                  | Epidemiological Context | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention                  |
|----------|-----------------|------------------------------|-------------------------|-------------------|-----------|----------------|------------------|-----------------------------------|
| 11 [145] | 2016            | Passive notification (CDCP)  | Ns1 IgM                 | NA                | N = 83    | Mild           |                   | Aedes aegypti (albopictus) (M)    |
| 12 [146] | 2003–2004       | Sero-prevalence              | Clinical signs IgM IgM  | Seroconversion    | N = 33    | NA             |                   | Aedes aegypti (O)                 |
| 13 [147] | Jul–Aug 2014    | Passive notification (NNIDRS) | Clinical IgG PCR        | NA                | N = 165   | NA             |                   | Aedes albopictus (aegypti) (M)    |
| 14 [148] | Jan–Dec 2014    | Passive notification China CDC | Clinical or laboratory diagnosis | NA                | 37,386    | Spatially clustered in central districts | Aedes (M)                        |
| 15 [149] | 2004–2011       | Passive notification (CDC)   | IgM                     | NA                | NA        | Heterogeneous  |                   | Aedes aegypti (albopictus) (M)    |
| 16 [150] | 2015            | Passive notification (CDC)   | IgM                     | NA                | N = 22,740 P = 12.06 per 1000 | 3 Clusters (Moran’s I) | Aedes aegypti and albopictus (M) |
| 17 [151] | 2010            | Passive notification (SIVIGILA) | Clinical signs IgM     | NA                | N = 9287  | 3 Clusters Heterogeneous (Moran’s I) | Aedes aegypti (M)               |
| 18 [152] | 1996–2002       | Passive notification (SINAN) (SISVE) | Clinical IgM         | NA                | N = 89,607 | Heterogeneous |                    | Aedes aegypti (M)                |
| 19 [153] | 2006–2010       | Passive notification (DHO) (SJMC) | NA                     | NA                | NA        | 5 Hotspots     |                   | Aedes (aegypti) (M)               |
| 20 [154] | 3–11 May 2013   | Sero-incidence               | IgM RT-PCR              | DENV-1 DENV-2 DENV-3 | N = 210 of 1500 | No clustering               | Aedes aegypti (M)                |
### Table A2. Cont.

| ID [Ref.] | Start–End Years | DATA Source | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------|-----------|-----------------|------------------|-----------------|
| 21 [155]  | 1995–1998       | Passive notification (IPEEDP) | NA | DENV-3 and co-circulation | N = 26,423 I = 112.7 per 100,000 (1997) | Heterogeneous | *Aedes aegypti* (M) |
| 22 [156]  | May-Sep 2012    | Sero-prevalence survey | IgM or IgG capture ELISA | NA | 37,386 | 42 cases, 42 intradomestic, and 42 population controls | *Aedes* (M) |
| 23 [157]  | 2005–2008       | Passive notification (DOH) | NA | NA | N = 8,812 | Heterogeneous | *Aedes* (M) |
| 24 [158]  | 2013–2014       | Passive notification (MOH) | Clinical NS1 or RNA-PCR | DENV-1 (dominant) and DENV-2 | N = 22,170 I = 410 (2013) N = 18,338 I = 335 (2014) | NA | *Aedes aegypti* (albopictus) (O) |
| 25 [159]  | 18–19 Aug 2000  | Primo and secondary Sero-incidence | IgM IgG | DENV-2 | I = 98 per 1000 | NA | *Aedes* (O) |
| 26 [160]  | Oct 2001        | Sero-incidence | Clinical IgM IgG | DENV-1 | I = 389 per 1000 | Confined area | *Aedes albopictus* (O) |
| 27 [161]  | 1 Jun–31 Jul 1999 | Passive notification (PHCC) | Clinical IgM | DENV-1 DENV-2 | N = 34 clinical NA | NA | *Aedes aegypti* (M) |
| 28 [162]  | Jul–Nov 2007, Apr 2008 | Sero-prevalence and recent cases survey | Clinical IgM IgG RT-PCR | DENV-2 | NA | Hotspots patterns | *Aedes aegypti* (albopictus) (O) |
| 29 [163]  | 2014–2015       | Passive notification Taiwan Centers for Disease Control (CDC) | IgM, nucleotide sequence, viral isolation | NA | 15,394 for 2014, 42,932 for 2015 | Hotspots of dengue epidemic in urban areas | *Aedes aegypti and Ae. albopitus* (M) |
| 30 [164]  | Jan–Sep 2014, Mar–Jun 2015 | Sero-prevalence | RT-PCR, NS1 test, ELISA and IgM | NA | 72 | Heterogeneous | *Aedes aegypti* (M) |
Table A2. Cont.

| ID [Ref.] | Start–End Years | DATA Source | Epidemiological Context | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------------|-----------------|------------------|-----------------|
| 31 [165]  | 2008–2013       | Passive notification DF and DHF cases, HD of Sleman district, and PHC | NA | NA | 1150 | Dengue incidents are clustered for each year | Aedes aegypti (M) |
| 32 [166]  | 2006–2010       | Passive notification (JHA) | Clinical | NA | NA | Heterogeneous | Aedes aegypti (M) |
| 33 [167]  | 1 Aug–21 Dec 2011 | Passive notification (NHTD) | Clinical signs RT-PCR | DENV-2, DENV-1 | N = 140 | 24 infectious foci | Aedes (O) (95%) aegypti (5%) albopictus |
| 34 [168]  | March–Oct 1986  | National sero-prevalence survey | Antigens test | NA | NA | Stratified | Aedes aegypti (O) |
| 35 [169]  | Aug–Oct 2007    | Sero-incidence (Hospital and PHO) | IgM, IgG, and clinical signs | NA | 1200 | NA | Aedes (aegypti) (M) |
| 36 [170]  | May–Nov 2002    | Passive notification (CDCPG) | NA | NA | N = 1069 | 2 clusters | Aedes aegypti and albopictus (M) |
| 37 [171]  | 2014            | Passive notification China CDC | NA | NA | 40 379 | Spatio-temporal dengue kernels | Aedes aegypti (M) |
| 38 [172]  | 2012            | Passive notification | Clinical signs | NA | P = ? per 10^5 | Heterogeneous. | Aedes aegypti (albopictus) (M) |
| 39 [173]  | 2006–2014       | Passive notification China CDC | Clinical signs, and lab. confirmed | NA | NA | Spatio-temporal clustering | Aedes albopictus (M) |
| 40 [174]  | 2012–2015       | Passive notification, the Punjab Health Department | NA | NA | 377 for 2012, 871 for 2013, 133 for 2014 and 49 for 2015 | NA | Aedes aegypti and Ae. albopictus (M) |
Table A2. Cont.

| ID (Ref.) | Start–End Years | DATA Source | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------|-----------|-----------------|------------------|----------------|
| 41 [175]  | 2006–2015       | The Health Department of Municipal Corporation of Delhi | NA | NA | NA | NA | *Aedes mosquitoes (M)* |
| 42 [176]  | 2008–2015       | Passive notification (SIVIGLIA) | Clinical signs | NA | N = 27,301 P = 1359 per 10^5 | NA | *Aedes aegypti (M)* |
| 43 [177]  | May–Sept 1995   | Serosurvey | Hemagglutination inhibition assay, Clark and Cassals | DENV-2 | [n = 203] | Foci | *Aedes aegypti (M)* |
| 44 [178]  | 1999–2007       | Passive notification Ministerio de Salud | Clinical and serologic | NA | N = 137,719 | Heterogeneous. | *Aedes aegypti (M)* |
| 45 [179]  | 2001–2010       | Passive notification SIVIGILA | NA | NA | NA | NA | *Aedes aegypti (M)* |
| 46 [180]  | 1994–1998, 1998–2002 | Passive notification A.L. | NA | NA | N = 13,998 | Heterogeneous, clusters (Moran’s I) | *Aedes aegypti (M)* |
| 47 [181]  | 2011–Aug 2017   | The State Secretariat of Health | NA | NA | From 475 to 43,359 yearly | NA | *Aedes aegypti (M)* |
| 48 [182]  | Jun–2006 Mars 2007 | Sero-prevalence survey | SN | NA | 709 11.9% | Heterogeneous | NA |
| 49 [183]  | Oct–Nov 2014    | Sero-prevalence survey | IgG ELISA | NA | N = 3194 children I = 69.4% | NA | *Aedes (M)* |
| 50 [184]  | 2013            | Passive notification China CDC | Clinic IgG PCR | NA | I = 28,896 per 10^5 | Highly clustered Hot and cold spot | *Aedes albopictus (aegypti) (M)* |
| ID [Ref.] | Start–End Years | DATA Source | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------|-----------|-----------------|------------------|----------------|
| 51 [185]  | 2014            | Passive notification China CDC | NA   | NA         | 37,380          | Space-time clustering | *Aedes albopictus (M)* |
| 52 [186]  | 1999            | Sero-prevalence IgM | NA   | NA         | Prevalence(IgM) P = 1.3% (Laredo) P = 16% (Nuevo Laredo) | Across the boarder | *Aedes aegypti (O)* |
| 53 [187]  | 2012, 2013, 2014, and 2017 | Passive notification China CDC | Clinical or laboratory diagnosis | NA | 36,344 for 2014, NA for other years | Spatially clusted for the each year | *Aedes albopictus (M)* |
| 54 [188]  | Jan–Dec 2012    | Passive notification | NA   | NA         | 1058            | Hotspots patterns | *Aedes (M)* |
| 55 [189]  | Nov 1991        | Sero-incidence survey (primary and secondary cases) IgM | IgG | NA | I = 18% (N = 59 of 331) | Agglomerated | *Aedes aegypti (O)* |
| 56 [190]  | 24 Jan 11 May 2004 | Passive notification (SiNaVE) | PCR IgM | IgG | N = 487 | Hot spots | *Aedes aegypti (M)* |
| 57 [191]  | 2005–2010       | Passive notification (DOH) | NA   | NA         | NA              | Heterogeneity | *Aedes (M)* |
| 58 [192]  | 2010–2015 (Geylang) 2013–2015 (Singapore) | Passive notification Ministry of Health | DENV 1-2-3-4 | NA | N = 353 (Geylang, 2014–2015) | 13 Clusters in Geylang (Moran’s Index) | *Aedes aegypti and albopictus (O)* |
| 59 [193]  | 2010            | Passive notification (NIMH) | NA   | DENV-1     | N = 2019 I = 84 per 10^5 | Hotspots patterns | *Aedes aegypti (M)* |
| 60 [194]  | 1994            | All hospitals notifications | Hemagglutination inhibition test of Clarke and Casals | NA | 0 to 21 cases monthly | All areas | *Aedes aegypti and albopictus (O)* |
| ID [Ref.] | Start–End Years | DATA Source | Epidemiological Context | Diagnostic Method | DENV-Type | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|-----------------|-------------|-------------------------|-------------------|-----------|----------------|-----------------|-----------------|
| 61 [195]  | May–Jun 1998    | Sero-prevalence | NA                      | DENV-1 and 2      | P = 68.7% | NA             | Aedes aegypti (O) |
|           | 1998-1999       | Sero-incidence | NA                      |                   | I = 70.6% | NA             |                 |
| 62 [196]  | 2002            | Passive notification | Clinical signs | DENV-1 DENV-2     | N = 368,460 | Highly Heterogeneous | Aedes aegypti (M) |
| 63 [197]  | 2008–2009–2010  | Passive Delhi surveillance system | IgM              | NA              | N = 5998 (2010) | Spatio-temporal clusters | Aedes aegypti (M) |
| 64 [198]  | 1995–2012       | Passive notification (DASS) | Clinical signs Lab. confirmed | NA              | N = 24,272 | Highly Heterogeneous | Aedes aegypti (M) |
| 65 [199]  | Jan–Dec 1998    | Passive notification (Health Department) | WHO criteria       | NA              | N = 287 DH/DHF | Some points clustering (Moran’s I) | Aedes (O) |
| 66 [200]  | 1978–2014       | Passive notification (NIDRS-CDC) | Phylo-genetic.     | DENV-1           | NA       | NA             | Aedes albopictus (O) |
| 67 [201]  | 2008–2009       | Sero-prevalence survey (Malaya University) | IgG ELISA         | NA              | N = 1,410 childrens | NA             | Aedes (M) |
| 68 [202]  | 2009            | Passive notification Hanoi Hospital | Clinical signs     | NA              | N = 73 DF/DHF | NA             | Mosquitoes (O) |
| 69 [203]  | 2002 2003       | Passive notification (Health Department) | Clinical signs     | NA              | N = 1,434 | NA             | Aedes aegypti (M) |
| 70 [204]  | May–Sep 2001    | Sero-incidence survey | IgM (ELISA)        | NA              | N = 1750 1 = 6.5% and I = 3.1% | One Sero-Positive cluster | Aedes aegypti (M) |
Table A2. Cont.

| ID [Ref.] | Start–End Years | DATA Source | Epidemiological Context | Number of Cases | Spatial Variation | Vectors Mention |
|-----------|----------------|-------------|-------------------------|-----------------|------------------|-----------------|
|           |                |             |                         |                 |                  |                 |
| 71 [205]  | 2001–2003      | Sero-incidence survey | IgM | NA | NA | 4 clusters | Aedes (M) |
| 72 [206]  | 2011–2015      | Sero-prevalence | NA | NA | 240 DHF patient cases | NA | Aedes (M) |
| 73 [207]  | July 1982      | Sero-incidence survey | Hemagglutination | DENV-1 | I = 35% (Salinas) |
|           |                |             |                         | DENV-4 | I = 26% (Manati) | NA | Aedes aegypti (O) |
| 74 [208]  | Jun 2007–Jan 2008 | Passive notification (Taiwan-CDC) | Clinical signs Lab. confirmed | NA | N = 1403 | Various space-time clusters | Aedes aegypti and albopictus (M) |
| 75 [209]  | Mar 2011–May 2012 | Sero-prevalence survey | IgG | NA | N = 156 school children (age 7–18) | 3 clusters | Aedes mosquitoes (M) |
| 76 [210]  | Jan–Dec 2014   | Passive notification China CDC | Clinical sign, lab. or viral isolation | NA | 30,553 | High density in several districts | Aedes albopictus (M) |
| 77 [211]  | Apr 2005–Feb 2013 | Sero-incidence survey | RT-PCR IgM-IgG conversion | DENV-1 | N = 395 of 1703 (age ≥ 18) | Spatial gradient | Aedes aegypti (M) |
| 78 [212]  | Sep 2008–Aug 2009 | Passive notification (DASS) | Clinical signs IgM PCR NS1 analyses | (DENV-1) | N = 2310 I = 23.7 per 1000 | North to South gradient clusters (Moran’s I) | Aedes aegypti (M) |
| 79 [213]  | 2012–2013 | Sero-incidence survey | IgM PCR | NA | N = 3369 I = 34.5 per 10³ | Widely homogeneous | Aedes aegypti (M) |
Appendix A.3. Landscape Factor Production and Landscape-Dengue Relationships Table

Table A3. Data extracted from the 78 articles on the landscape factor production (type of source), on the landscape factor classification according to groups and subgroups, and on the dengue-landscape relationship (three-valued interpretation: +, −, or NS, and statistical method performed).

| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------------|--------------------|
|           |             | Entomological observation |                | *Aedes albopictus* larvae | +                           | Vector breeding sites (at household level) | Correlation and simple regression model |
| 1 [135]   | Survey questionnaire |                |                | *Aedes aegypti* larvae   | NS                          |                                    |                    |
| GIS data  | Land use    | Infrastructure level | Proximity to the hospitals | +                        | Virus screening (at wards level) |                                    |                    |
|           | Housing type and characteristics |                |                | Villa w/o garden       | NS                          | Human–Vector encounter (at household-level) | Odds ratio Multivariate logistic regression |
| 2 [136]   | Survey questionnaire |                |                | Villa with garden       | NS                          |                                    |                    |
| Land use  | Infrastructure level | Presence of a sewage network | −                           | Vector breeding sites (at household-level) |                            |                                    |                    |
| Entomological observations | Presence of mosquitoes at home | +                        | Exposure to mosquitoes bite (at household-level) |                            |                                    |                    |
| Human immunity | Previous history of Dengue | +                        | Virus Exposition (at household-level) |                            |                                    |                    |
Table A3. Cont.

| ID [Ref.] | Data Source          | Data Group         | Data Sub-Group     | Landscape Factors                  | Three-Valued Interpretation | Potential Proxy of Statistical Method | Database, Method |
|-----------|----------------------|--------------------|--------------------|-----------------------------------|-----------------------------|---------------------------------------|------------------|
| 3         | Landsat 5 TM image   | Land cover         | Surface Temperature| Urban heat islands                | +                           | Vectors resting sites and virus replication (at large-admin level) | Multiple cluster analysis |
|           |                      |                    | Vegetation         | Normalized Difference Vegetation Index (NDVI) | -                           | Vectors breeding and resting sites (at large-admin level) |                  |
|           | Survey questionnaire | Land use           | Urban Typology     | Slums-like areas                  | NS                          | Human-Vector encounter (at large-admin-level) |                  |
|           | Housing type and characteristics | Housing characteristics | Screens on windows | NS                               | Vectors exposure (at household-level) | Multivariate Analysis |                  |
|           | Land use             | Construction material | Mixed type of house construction | NS                               | Vector breeding site (at neighborhood-level) |                  |
|           |                      | Cropland           | Taro farming       |                                   | +                           |                                       |                  |
| 4         | Survey questionnaire | Entomological observation | Presence of Aedes albopictus | +                               | Vector exposure (at household-level) | Univariate and Multivariate Analysis |                  |
|           |                      |                    | Presence of Aedes aegypti | +                               | Vector exposure (at household-level) |                  |
|           |                      |                    | Larvae-positive habitats | +                               | Vector breeding site (at neighborhood-level) |                  |
|           | Housing type and characteristics | House characteristics | Animals water pans | +                               | Vector breeding site (at household-level) |                  |
|           | Entomological observation | Presence of Aedes | +                               | Vector exposure (at household-level) |                  |
| 5         | Survey questionnaire | Entomological observation | Larvae abundance | NS                               | Vectors breeding site (at neighborhood-level) | Cross-lagged correlation |                  |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|----------------------------------|-------------------|
| 6 [140]  | Survey questionnaire | Entomological observation | Aedes Eggs indicators | NS | Vector breeding site (at neighborhood-level) | Generalized additive model |
| 7 [141]  | GIS data | Human density | Human density | + | Human exposure to virus (at neighborhood-level) | Linear statistic stratification |
| 8 [142]  | Survey questionnaire | Housing type and characteristics | House characteristics | Households with water supply | | | GLMM GAM |
| 8 [142]  | Survey questionnaire | Housing type and characteristics | House characteristics | Households with regular water supply | | | GLMM GAM |
| 8 [142]  | Survey questionnaire | Housing type and characteristics | House characteristics | Households with a sewage system | | | GLMM GAM |
| 8 [142]  | Survey questionnaire | Housing type and characteristics | House characteristics | Households with a garbage collection | | | GLMM GAM |
| 9 [143]  | Survey questionnaire | Land use | Infrastructure level | Absence of air conditioning | + | Vector exposure (at household-level) | Multivariate logistic regression |
| 9 [143]  | Survey questionnaire | Land use | Infrastructure level | Lack of street drainage | + | Vector breeding site (at neighborhood-level) | Multivariate logistic regression |
| 9 [143]  | Survey questionnaire | Entomological observation | Presence of Aedes habitats | + | | | Multivariate logistic regression |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|--------------------------------------|
| 10 [144]  | Landsat 8 image | Land use | Infrastructure level | Urbanization level | + | Human-Vector encounter (at small-admin level) |
|           | GIS data | | | Road density | + | Human mobility at small-admin level |
|           | MODIS image | Land cover | Vegetation | NDVI and VFC | − | Vectors breeding and resting sites (at small-admin level) |
|           | GIS data | | Water-areas | Water-body areas | − | |
|           | Landsat 8 and Quickbird images | Land use | Urban Typology | % of urban villages | + | Human-Vector encounter (at small-admin level) |
| 11 [145]  | Survey questionnaire | Human mobility | Long-distance human mobility | Foreign inhabitants | + | Human and Virus mobility (at small-admin level) |
|           | | | | | | GLM |
| 12 [146]  | Survey questionnaire | Entomological observations | | Adults and immatures *Aedes* | + | Exposure to mosquitoes bite (at household-level) |
|           | | | | Rate of *Aedes* pupae per person | + | |
| 13 [147]  | Tele-interview survey questionnaire | Housing type and characteristics | Housing type | Old flats | + | |
|           | | | Sheds | | + | Vector exposure at household-level |
|           | | | Screens on windows | | | Logistic regression models and Odds Ratio (OR) |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Dengue-Landscape Relationship | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------|--------------------|
| 14 [148]  | 2.5m SPOT 5 image GIS data (Baidu map) | Land use | Infrastructure level | Road network density | + | Human-vector encounter (at neighborhood level) | Geographical detector |
|           |             |            | Infrastructure level | Subway lines network density | + | Human-vector encounter (at neighborhood level) |                      |
|           |             |            | Water-areas | Aging infrastructure | + | Vector breeding site (at neighborhood level) |                      |
|           |             |            | Human density | Ponds area | + | Human exposure to virus (at neighborhood level) |                      |
|           |             |            | Human density | Number of the people on the building | + | Human exposure to virus (at neighborhood level) |                      |
| 15 [149]  | GIS data   | Land use   | Infrastructure level | % of canals and ditches | + | Vectors breeding sites (at small admin-level) | Quantile regression |
|           |             |            | Infrastructure level | Interaction ditches-residential areas | + | Human-Vector encounter (at small admin-level) |                      |
| 16 [150]  | GIS data   | Land use   | Urban Typology   | Residential area | + | Human-Vector encounter (at small admin-level) | Quantile regression |
|           | Land use   | Urban Typology | Recreation area | NS |                              |                              |                    |
|           | Land use   | Urban Typology | Business area  | NS |                              |                              |                    |
|           | Land cover | Cropland   | Agriculture area | NS |                              |                              |                    |
|           | Land cover | Cropland   | Water areas    | Wetland | − | Vectors breeding sites (at small-admin level) |                              |
|           | Land cover | Cropland   | Water areas    | NS |                              |                              |                    |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors          | Three-Valued Interpretation | Potential Proxy of Statistical Relationship | Statistical Method |
|----------|-------------|------------|----------------|----------------------------|----------------------------|--------------------------------------------|-------------------|
| 17 [151] | GIS data    | Land use   | Infrastructure level | Proximity to parks       | +                          |                                            |                   |
|          |             |            | Topography    | Proximity to rivers       | NS                        |                                            |                   |
|          |             |            | Urban Typology | Proximity to tyre shops   | NS                        | Human-Vector encounter (at neighborhood-level) | GWR               |
|          |             |            | Infrastructure level | Proximity to water pumps | NS                        |                                            |                   |
|          |             | Land use   | Urban Typology | Proximity to cemeteries   | NS                        |                                            |                   |
|          |             |            | Urban Typology | Proximity to plant nurseries | +                        |                                            |                   |
|          |             |            | Infrastructure level | Proximity to houses with a sewage system | −                        |                                            |                   |
| 18 [152] | Survey questionnaire | Land use | Infrastructure level | % of households with no piped water | NS                        | Vectors breeding sites (at small-admin level) | Multivariate regression |
|          |             |            | Human density | Population density        | NS                        | Human exposure to virus (at small-admin level) |                   |
|          |             | Land use   | Urban Typology | Ratio (Nb commercial) (Nb Households) | NS                        | Human-Vector encounter (at small-admin level) |                   |
Table A3. Cont.

| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Dengue-Landscape Relationship | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|------------------------------|--------------------|
| 19 [153]  | IKONOS image GIS data | Land use | Urban Typology | Residential areas | + | Human-Vector encounter (at small-admin level) | Layers super-imposition |
| 20 [154]  | Survey questionnaire (assisted by Google Earth imagery) | Land use | Urban Typology | Industrial areas | + | Human mobility (at regional-level) | OR (95 % CI) Logistic regression |
| 21 [155]  | Topographic data | Land use | Infrastructure level | Public services availability | − | Human-Vector encounter (at large-admin level) | Bivariate statistics |
| ID [Ref.] | Data Source       | Data Group                | Data Sub-Group | Landscape Factors                          | Three-Valued Interpretation | Potential Proxy of Statistical Method | Statistical Method                |
|-----------|-------------------|---------------------------|----------------|--------------------------------------------|----------------------------|-------------------------------------|----------------------------------|
| 22 [156] | GIS data (GPS data logger) | Human mobility            |                | Number of visits out of the municipality’s administrative limits + | Human and virus mobility (at city level) | + | Conditionnal and multiple logistic regression |
| 23 [157] | GIS data          | Land use                  | Infrastructure level | Residential with commercial industrial areas + | Human-Vector encounter (at small-admin level) | + | Layers super-imposition |
| 24 [158] | Survey questionnaire, GIS data | Entomological observation |                | Aedes house index + | Vector exposure (at neighborhood-level) | + | Linear correlation (Spearmann) |
| 25 [159] | Survey questionnaire | Entomological observation |                | Discarded containers + | Vector breeding sites (at household-level) | + | Univariate and Multivariate analysis (Odds Ratio) |
| 26 [160] | Survey questionnaire | Entomological observation |                | Lot size NS | Human density (at neighborhood-level) | − | Multiple logistic regression (Odds ratios) |
|           | Land use          | Urban Typology            |                | Neighbor proximity − | Vector exposure (at household-level) | + | |
|           | Land cover        | Vegetation                |                | Distance house-vegetation + | Vector breeding sites (at household-level) | + | |
|           | Topography        | % Shaded                  |                | % households with Aedes albopictus larvae NS | Vector breeding sites (at neighborhood-level) | + | |
|           | Housing type and characteristics | Construction material | Wood-construction | NS | Vectors exposure (at household-level) | − | |
|           | Housing type      | Single-level houses       |                | | |
|           | % Shaded          | Vegetation                | Tree height    | + | Vectors resting sites (at household-level) | + | |
|           | % Shaded          | Vegetation                | % Shaded       | + | |
|           | Housing type and characteristics | Home with birds | Screens on windows | + | Vector exposure (at household-level) | − | |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Dengue-Landscape Relationship | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|------------------------------|-----------------------------|-------------------------------|-------------------|
| 27 [161]  | Survey questionnaire | Topography | Street orientation to the wind | + | Vectors mobility (at small-admin level) | Odds ratios |
|           | Housing type and characteristics | Housing characteristics | Gutter-rain water | + | Vector breeding sites (at small-admin level) |
|           | Land use | Infrastructure level | Inefficient waste collection | + | |
| 28 [162]  | Survey questionnaire | Land use | Urban Typology | Slum area | + | Human-Vector encounter (at neighborhood-level) |
|           | Entomological observation | Mosquito abundance | | NS | Vector exposure (at neighborhood-level) |
|           | Land use | Urban Typology | Commercial activity areas with human movements | + | Human-Vector encounter at neighborhood-level |
| 29 [163]  | GIS data | MODIS image | NDVI | – | |
|           | Land cover | Vegetation | Forest | – | |
|           | Land use | Land cover | Grassland | – | Vector breeding and resting sites (at city level) |
|           | Cropland | Agricultural areas | – | | Spearman correlation GLMM |
|           | Urban typology | Park | + | | |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of Statistical Method | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|----------------------------|----------------------------------------|-------------------|
| 30 [164]  | Survey questionnaire | Housing type and characteristics | Housing characteristics | Highly shaded patio | + | Vector exposure (at household level) | Bivariate analysis using Chi-square, Fisher’s Exact or t-tests |
|          |             |            |                | Proximity to abandoned property | + |                       |                                |
|          |             |            |                | Lack of piped water inside the house | + | Vector breeding site (at household level) |                                |
|          |             |            |                | Daily garbage collection | – |                       |                                |
|          |             |            |                | Standing water in various recipient types | NS |                       |                                |
|          |             |            |                | Screens on all windows | NS | Vector exposure (at household level) |                                |
| 31 [165]  | Quickbird image | Land cover | Urban typology | % of built-up area with vegetation surrounding | + | Human-vector encounter (at neighborhood-level) | Spearman and Pearson correlation |
|          |             |            |                | Only built-up area | – | Vector mobility (at large administrative-level) |                                |
| 32 [166]  | SPOT 5 image | Land use | Urban Typology | Quality of neighborhood | – | Human-Vector encounter (at large-admin level) | GWR |
| 33 [167]  | Survey questionnaire | Entomological observation |                | $Aedes aegypti$ population density | + | Vector exposure (at neighborhood-level) | Spearman correlation coefficient |
|          |             |            |                | $Aedes albopictus$ population density | NS |                       |                                |
## Table A3. Cont.

| ID [Ref.] | Data Source   | Data Group            | Data Sub-Group                  | Landscape Factors | Three-Valued Interpretation | Potential Proxy of Statistical Method | Statistical Method |
|-----------|---------------|-----------------------|--------------------------------|------------------|-----------------------------|--------------------------------------|-------------------|
| 34        | Survey questionnaire | Entomological observation | % of houses with larva on the premises | +                | Vector exposure (at household-level) |                                      |                   |
| 35        | Survey questionnaire | Urban Typology | Number of house floors | NS               |                              |                                      |                   |
|           |               |                       | Floor of principal living | NS               |                              |                                      |                   |
| 36        | MODIS-VI image | Land use              | % of construction area | +                | Human-Vector encounter (at large-admin level) | Generalized linear model logistic regression |                   |

### Landscape Factors

- **Survey questionnaire**: % of houses with larva on the premises
- **Entomological observation**: % of houses with uncovered water containers
- **Topographic data**: Altitude
- **Land use**: % of construction area
- **Vegetation**: % of shrubs
- **Water-areas**: % of wet grassland and % of water area
- **Cropland**: % of paddy field

### Dengue-Landscape Relationship

- **Vector exposure (at household-level)**
- **Vector breeding sites (at neighborhood level)**
- **Vector mobility (at regional level)**
- **Virus exposition (at small-admin level)**
- **Human-Vector encounter (at large-admin level)**
Table A3. Cont.

| ID [Ref.] | Data Source | Data Group  | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of Statistical Method |
|-----------|-------------|-------------|----------------|-------------------|----------------------------|--------------------------------------|
| 37 [171]  | GIS data    | Land use    | Infrastructure level | High-density road networks | +                           | Human and virus mobility (at neighborhood-level) |
|           |             |             |                 | Proximity to narrow roads | +                           | Analysis of Variance (ANOVA)          |
| 38 [172]  | Survey questionnaire | Land use | Infrastructure level | Housing type and characteristics | Poor housing condition | +                           | Human-Vector encounter (at small-admin level) |
|           |             |             |                 | Housing characteristics |                             | (Moran’s I) Negative binomial model    |
| 39 [173]  | Survey questionnaire (the National Bureau of Statistics of China) | Land use | Urban typology | Urban, urban-rural and rural communities | NS                          | Human-vector encounter (at neighborhood-level) |
|           |             |             |                 | Housing type and characteristics |                             | Univariate logistic regression Stepwise logistic regression |
| 40 [174]  | Google earth | Land cover  | Urban Typology | % of built-up area | +                           | Human-vector encounter (at large admin-level) |
|           |             |             |                 | Urban typology |                             | Descriptive statistical analysis      |
| 41 [175]  | Topography data and high resolution satellite images | Land use | Infrastructure level | Distance from drainage networks | −                           | Vector breeding site (at city-level) |
|           |             |             |                 | Urban typology | Built-up density | +                           | Human-vector encounter (at city-level) |
|           |             |             |                 | Water areas | Distance from water bodies | −                           | Vector breeding site (at city-level) |
|           |             |             |                 | Vegetation | Vegetation density | −                           | Vector resting site (at city-level) |
|           |             |             |                 | Topography data and high resolution satellite images | Distance from drainage networks | −                           | Poisson regression |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------------|--------------------|
| 42 [176]  | Landsat     | Land cover | Vegetation     | Normalized difference vegetation index (NDVI) | Vectors breeding and resting sites (at small-admin level) | Pearson coefficient Bayesian model |
|           | MODIS       | Surface Temperature | Urban heat islands (UHI) | | Vectors and Virus replication (at small-admin level) | |
| 43 [177]  | Survey questionnaire | Housing type and characteristics | Housing characteristics | Presence of house screening | | |
|           |             |             |                | Presence of rainwater tanks on the property/two residential blocks | Human-Vector encounter (at household-level) | Stepwise logistic regression analysis (odds ratio) |
|           |             |             |                | Presence of evaporative cooling units | | |
| 44 [178]  | Census data | Housing type and characteristics | Housing characteristics | Presence of a suspected case of dengue household / two residential blocks | | |
|           |             |             |                | Presence of well-condition house | Human-Vector encounter (at small-admin level) | Pearson, Spearman, and multiple analysis |
|           | MODIS       | Land cover  | Vegetation     | Enhanced Vegetation Index | Vectors breeding and resting sites (at large scale) | |
|           | Topographic data | Topography | Altitude of city center | | Vector mobility (at large scale) | |
| 45 [179]  | Landsat image | Land cover  | Vegetation     | NDVI | Vectors breeding and resting sites (at city level) | Simple linear regression |
| ID [Ref.] | Landscape Factors Production | Dengue-Landscape Relationship |
|-----------|------------------------------|------------------------------|
|           | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
| 46 [180]  | Survey questionnaire | Housing type and characteristics | Housing type | % of one-story home | + | Vector exposure (at small-admin level) | Spatial regression |
| 47 [181]  | Landsat 8-OLI TIRS | Land cover | Vegetation | NDVI | NS | Vector breeding or resting sites (at large administrative-level) | Linear stepwise regression |
|           |             |             | Water areas | NDWI | NS |                         |                                     |
|           |             |             | Urban typology | NDBI | NS | Human-vector encounter (at large administrative-level) |                                     |
|           |             |             | Surface temperature | LST | NS | Vectors and virus replication (at large administrative-level) |                                     |
| 48 [182]  | Survey questionnaire | Housing type and characteristics | Housing type | Apartment | − | Vector exposure (at household-level) | OR (95% CI) Logistic regression |
|           |             |             | House/shanty |           | + |                         |                                     |
|           |             |             | Land use | Urban Typology | Temporary/unplanned/slum | − |                         |                                     |
| 49 [183]  | Survey questionnaire | Housing type and characteristics | Housing type | Single story attached building | − | Human-Vector encounter (at neighborhood-level) | Uni, multi-variate hierarchical logistic regression |
|           |             |             |             | Single story detached building | + |                         |                                     |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------------|-------------------|
|           | Census data | Infrastructure level | Prefectural boundary | Human-Vector encounter | + | Human-Vector encounter (at small-admin level) | GAM |
| 50 [184]  | GIS data    | Land use | Urban Typology | Urban and rural | + | Human exposure to virus (at small-admin level) | |
|           | Remote sensing images (unknown sensor) | Land cover | Vegetation | Normalized Difference Vegetation Index (NDVI) | + | Vectors breeding and resting sites (at small-admin level) | |
|           | GIS data    | Land use | Infrastructure level | Road density | + | Human mobility (at small-admin level) | Generalized additive model (GAM) |
| 51 [185]  | GIS data    | Infrastructure level | Road density | Human mobility (at large administrative-level) | + | | |
|           | Remote sensing images (not clear) | Land cover | Vegetation | NDVI | − | Vector breeding or resting sites (at large administrative-level) | |
|           | Survey questionnaire | Housing type and characteristics | Absence of air conditioning | Vector exposure (at household-level) | + | | |
| 52 [186]  | Survey questionnaire | Human mobility | No history of outside-travel | Human mobility (at regional-level) | + | | |
|           | Survey questionnaire | Land use | Urban Typology | Distances to neighboring houses | + | Human-Vector encounter (at neighborhood-level) | Univariate and Multivariate analysis |
Table A3. *Cont.*

| ID [Ref.] | Data Source          | Data Group       | Data Sub-Group | Landscape Factors                          | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method                          |
|-----------|----------------------|------------------|----------------|-------------------------------------------|-----------------------------|-----------------------------------|--------------------------------------------|
| 53 [187]  | GF-2 satellite image | Land use         | Urban typology | Urban villages associated to public transport | +                          | Human-vector encounter (at large administrative-level) | Pearson correlation and Geographically weighted regression (GWR) |
| 54 [188]  | World View 2 image   | Land use         | Urban typology | Mean size of pitched roof + Mean size of flatted roof | + –                          | Vectors breeding and resting sites (at neighborhood-level) | (Moran’s I) GWR |
| 55 [189]  | Survey questionnaire | Housing type and characteristics | Concrete construction | +                         | Vector exposure (at household-level) | Univariate and multivariate logistic regression methods |
| 56 [190]  | LANDSAT 5 TM satellite image | Land cover | Water-areas | Distance to river | +                           | Human-vector encounter (at neighborhood-level) | Visual interpretation Pearson correlation coefficient |
|           |                      |                  | Vegetation     | Distance to Vegetation                   | +                           | Vectors breeding and resting sites (at neighborhood-level) | |
|           |                      |                  | Vegetation     | Tasseled cap vegetation                  | +                           | Human presence (at neighborhood-level) | |
|           |                      |                  | Water-areas    | Tasseled cap wetness                     | +                           |                                   | |
|           |                      |                  | Built-up       | Tasseled cap brightness                  | +                           |                                   | |
Table A3. Cont.

| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|------------------------------|-----------------------------------|-------------------|
| 57 [191]  | ALOS Google Earth GIS data | Land use | Urban Typology | Dense populated areas surrounded by vegetation | + | Vector exposure (at neighborhood-level) | Geo-spatial analysis |
|           |             |            |                | Institutions 40%, religious places (18%) market (15%) | + | Human-Vector encounter (at neighborhood-level) |        |
| 58 [192]  | Census, OSM and GIS data | Land use | Urban Typology | High-rise housing | − | Human-Vector encounter (at neighborhood-level) | Chi-square test |
|           |             |            | Low-rise housing | + | Vectors breeding sites (at neighborhood-level) |        |
|           | Entomological survey | Entomological observation | Density of the urban drainage network | + | Vectors breeding sites (at neighborhood-level) |        |
| 59 [193]  | Census data | Land use | Urban Typology | Composite normalized housing condition index | + | Human-Vector encounter (at neighborhood-level) |       |
|           |             |            |                | + | Dengue reporting (at neighborhood-level) |       |
|           | Entomological survey | Entomological observation | Short distance from hospital | + | Vectors breeding sites (at neighborhood-level) |       |
|           |             |            |                | + | Access to piped water |       |
| 60 [194]  | Entomological survey | Entomological observation | Breteau Index | NS | Vectors breeding sites (at neighborhood-level) |       |
|           |             |            |                | Breteau index | NS | Vectors breeding sites at household-level |       |
|           |             |            |                | House index | NS |                                |       |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Dengue-Landscape | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|------------------|--------------------|
|           |             |            |                | Landscape Factors Production | Relationship |                     |
| 61 [195]  | Census data | Human density |                | Human density | + | Human exposure to virus (at neighborhood-level) | Pearson coefficients |
|           | Entomological survey | Entomological observation | | Premise index | NS | Vectors breeding sites at neighborhood-level | Risk ratio |
| 62 [196]  | Census data | Human density |                | % of urban population | + | Human exposure to virus (at small-admin level) | Spearman coefficient Multi-linear regression |
|           |             | Land use | Infrastructure level | % of population connected to water network | − | Vectors breeding sites (at small-admin level) | |
|           |             | Land use | Infrastructure level | % of coverage by Family health program | − | Human exposure to virus (at small-admin level) | |
| 63 [197]  | Census data | Land cover | Vegetation | Distance from forested areas | − | Human-Vector encounter (at neighborhood-level) | |
|           |             | Land use | Infrastructure level | Proximity to a sentinel hospital | − | Virus observation (at small-admin level) | |
|           |             | Land use | Urban Typology | Deprived areas with medium-high human densities | + | Human-Vector encounter (at small-admin level) | |
|           |             |            |                | Rich areas | + | | |
| 64 [198]  | Topographic survey | Topography | | Mean Altitude | − | Vector mobility (at city-level) | Pearson Coefficient |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of Statistical Method | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|----------------------------------|-------------------|
| 65 [199]  | Survey questionnaire | Land use | Urban Typology | House density | NS | Human-Vector encounter (at small-admin level) | Pearson coefficient |
|           |             | Land cover | % of shop-houses | + |                  |                                  |                   |
|           |             | Land cover | % of single houses | − |                  |                                  |                   |
|           |             | Land use | % of building | NS |                  |                                  |                   |
|           |             | Land use | % of slum | − |                  |                                  |                   |
|           |             | Housing type | % of empty houses | Human-Vector encounter (at neighborhood-level) | Spearman correlation coefficient |
|           |             | Construction material | % of brick-made houses | Vector breeding sites and vector mobility (at city-level) | Linear correlation |
| 66 [200]  | Landsat image | Land cover | Water-areas | Water surface | + | Vector breeding sites and vector mobility (at city-level) | Linear correlation |
|           |             | Land use | Urban Typology | % of developed land | + | Human-Vector encounter (at neighborhood-level) | Spearman correlation coefficient |
| 67 [201]  | Google Earth | Land cover | Vegetation | % of Vegetation | − | Human-Vector encounter (at neighborhood-level) | Spearman correlation coefficient |
|           |             | Water-areas | % of water surface | NS |                  |                                  |                   |
| 68 [202]  | Survey questionnaire | House type and characteristics | Living near open sewers | Vector exposure (at household-level) | Odds ratios |
|           |             | House characteristics | Mosquitoes presence in the house | + | Vector exposure (at household-level) | Odds ratios |
Table A3. Cont.

| ID [Ref.]  | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|------------|-------------|------------|----------------|-------------------|------------------------------|-----------------------------------|--------------------|
| 69 [203]   | MODIS-ASTER | Land cover | Vegetation     | EVI-NDVI          | −                            | Vectors breeding and resting sites (at small-admin level) | Pearson coefficient |
|            |             |            | Urban Typology | % Built area      | NS                           | Human-Vector encounter (at small-admin level)       |                     |
|            |             |            | Vegetation     | % Tree area       | NS                           | Vectors breeding and resting sites (at small-admin level) |                     |
|            |             |            | Urban Typology | % Built area      | −                            | Human-Vector encounter (at small-admin level)       |                     |
|            |             |            | Vegetation     | % Tree cover      | +                            | Vectors breeding and resting sites (at small-admin level) |                     |
| 70 [204]   | Survey questionnaire | Housing type and characteristics | Construction material | Stone and concrete | NS                           | Vector exposure (at household-level) | Logistic regression |
|            |             |            |                | Combination of stone and wood | NS                           |                     |                     |
|            |             |            | Housing characteristics | Screened windows | −                            |                     |                     |
|            |             | Land use   | Cropland       | Distance to orchards | +                            |                     |                     |
|            |             | Land cover | Urban Typology | % of densely built area in 200 m | −                            |                     |                     |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------------|--------------------|
| 71 [205]  | Survey questionnaire | Housing type and characteristics | Construction material | Wood/bamboo Households | - | Vector exposure (at household-level) | Logistic regression |
|           |             | Housing characteristics | Bednets | - |  |  |  |
|           |             | Land use | Cropland | Distance to orchards | - |  |  |
|           |             | Land cover | Water-areas | Distance to waterbodies | + | Human-Vector encounter (at neighborhood-level) |  |
|           |             | Land cover | Bare soils | % of bare soil in 200 m-buffer | - |  |  |
|           |             | Land use | Urban Typology | % of village area with Vegetation | NS |  |  |
| 72 [206]  | Survey questionnaire | Housing type and characteristics | Housing characteristics | Housing size | NS | Vector exposure (at household-level) | Bivariate analysis using t-test (ratio scale) and chi square (test nominal) scale |
|           |             | Housing characteristics | Non permanent wall | + | Vector breeding site (at household-level) |  |
|           |             | Land use | Urban Typology | Slum housing | + | Human-Vector encounter (at neighborhood-level) |  |
|           |             | Land cover | Vegetation | Tree height | + |  |  |
|           |             | Topography | Shade | + | Vectors resting sites (at household-level) |  |
| 73 [207]  | Survey questionnaire | Housing type and characteristics | Construction material | Wood structure | + | Vector exposure (at household-level) | Univariate and Multivariate analysis |
|           |             | Housing type and characteristics | Screens on windows | - |  |  |
|           |             | Entomological observations | Day-biting mosquitoes | + |  |  |
| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-----------------------------|-----------------------------------|--------------------|
| 74 [208]  | Survey questionnaire | Land cover | Bare soils       | Vacant grounds     | +                           | Vectors breeding and resting sites (at small-admin level) | Univariate and Multivariate analysis |
|           |             | Land use   | Urban Typology   | Empty house        | +                           |                                   |                    |
|           |             |           |                 | Markets-parks      | NS                          | Human-Vector encounter (at small-admin level) |                    |
|           |             | Human density |               | Population density | +                           | Human and virus mobility (at regional level) |                    |
|           |             | Human mobility |              | Commuting patterns  | +                           |                                   |                    |
| 75 [209]  | Survey questionnaire | Land use   | Urban Typology   | High rise residential apartment | +                           | Human-Vector encounter (at neighborhood-level) | t-test analysis analysis of variance, chi square, Uni-variate and multivariate logistic regression |
|           |             | Housing type and characteristics | Housing characteristics | Terraced house | −                           | Vectors breeding and resting sites (at household-level) |                    |
|           |             |           |                 | Vegetation surround | −                           |                                   |                    |
|           |             | Land use   | Urban Typology   | Single house        | −                           | Human-Vector encounter (at neighborhood-level) |                    |
|           | Entomological observation |              |                | Mosquito problem     | +                           | Vector exposure (at household-level) |                    |
| 76 [210]  | GF-1 image  | Land cover | Water            | NDWI               | +                           | Vector breeding and resting sites (at neighborhood-level) | Spearman rank correlation and Ordinary least square (OLR) |
|           | MODIS image | Land cover | Surface water    | LST day             | +                           | Vector resting site and virus replication (at neighborhood-level) |                    |
### Table A3. Cont.

| ID [Ref.] | Data Source | Data Group | Data Sub-Group | Landscape Factors | Three-Valued Interpretation | Potential Proxy of (at Unit Level) | Statistical Method |
|-----------|-------------|------------|----------------|-------------------|-------------------------------|------------------------------------|--------------------|
| 77 [211]  | Survey questionnaire | Housing type and characteristics | Housing characteristics | Multi-storey public flats | NS | Vector exposure (at household-level) | Multi-level logistic regression |
|           |             | Land use   | Urban Typology | Landed houses     | NS                           |                                    |                    |
|           |             | Human mobility | Use of public transportation | NS | Human mobility (at small-admin level) |                      |                    |
|           |             |            | Foreign workers dormitory or hostel | + | Human mobility (at regional level) |                      |                    |
| 78 [212]  | Census data | Land cover | Vegetation | Vegetation coverage | + | Vectors breeding and resting sites (at neighborhood-level) | Univariable and multivariable generalized linear model |
|           |             | Housing type and characteristics | Human density | Households crowding | + | Human-Vector encounter (at neighborhood-level) | |
|           |             | Housing type and characteristics |            | Households density | NS |                                    | |
|           |             | Housing type | Old buildings | + |                                    | |
|           |             |            | Degraded loggings | NS |                                    | |
|           |             |            | Apartment 2008–2009 | – | Vector exposure (at household-level) | |
|           |             |            | Apartment 2012–2013 | – |                                    | |
|           |             | Construction material | Cement loggings 2008–2009 | NS |                                    | |
|           |             |            | Cement loggings 2012–2013 | + |                                    | |
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