An Approach for Risk Maps of Vector-Borne Infectious Diseases: Ecological and Adaptive Capacity Indicators

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AN APPROACH FOR RISK MAPS OF VECTOR-BORNE INFECTIOUS DISEASES: ECOLOGICAL AND ADAPTIVE CAPACITY INDICATORS

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ABSTRACT

Complex interactions of ecological and climate indicators play a vital role in defining spatiotemporal patterns of vector-borne disease habitats and transmission. Vietnam is in the sub-tropical climate zone with high humidity and abundant precipitation, while unevenly distributed precipitation leads to frequently annual occurrence of drought and flooding. The increase in frequency and magnitude of severe weather extremes likely linked to climate change and anthropogenic processes highlights the demands of research in GeoHealth risk and adaptive capacity assessment. In this study, mapping vector-borne disease is made for revealing physical features of ecological indicators and its association with vector-borne diseases and adaptive capacity to illustrate how remotely sensed data products have been utilized in GeoHealth applications, surveillance, and vector-borne disease risk mapping in Vietnam. Additionally, it is to promise the possibilities of establishing disease early-warning systems with citizen participation and provide knowledge to support ecological and human health diseases research.

Index Terms: Vector-borne diseases; ecological indicators; GeoHealth.

1. INTRODUCTION

Deteriorated environmental, ecological, and climate conditions may increase the human's susceptibility to diseases and harm human health, thereby accelerating disease transmission [1, 2]. Vast amounts of studies were conducted to explore the scenarios that climate indicators and weather conditions may affect vector-borne disease transmission by directly influencing the viability of pathogens [3, 4, 5]. They very much focused on the mechanisms of diseases transmission, but not on their spatial distributions on the map. In addition, most of them are empirical studies, lack of comprehensive visualization and integration of climatic, ecological, environmental, and adaptive factors leaving a gap between understandings of the environmental, ecological, climate patterns, and prediction of the health risks for infectious diseases [5, 6, 7, 8]. There is a demand to generate risk maps integrating those environmental and climate indicators with adaptive capacity factors to define regions of vector-borne diseases. Unfortunately, in recent years climate change has been more seriously taking place in developing countries especially in Southeast Asia where have limited societies' capacity (such as inadequate medical care, less-effective communication, public health education, financial concerns) to prepare and respond to the threatened health issues resulting from climate change.

Remote sensing data has been instrumental in mapping the features of the earth's surface for decades. Recently, there has been an increasing trend on GeoHealth studies by use of remotely sensed data for mapping health risk and monitoring vector-borne diseases [1, 9]. This article provides further applications on how remotely sensed data can be used in health applications and assesses earth-observing satellites to detect and map environmental and climatic indicators, and adaptive capacity related to the spatial distribution of vector-borne diseases. We take advantages of remote sensing data to create risk maps of infectious diseases for whole Vietnam based on two groups of indicators, including environmental and adaptive capacity indicators. It is expected that this study can serve as an example for calling more attention and efforts of cross-disciplinary groups to benefit the products of spatiotemporal health risk maps associated with climatic, environmental, ecological conditions to minimize the negative impacts of climate change and environmental problems on human health.

2. METHODS

Multi-indicator analysis and risk assessment were conducted to derive a malaria risk map in Vietnam as shown in **Fig.1,** Vietnam Argo-ecological regions overlaid on land cover map. Risk is mainly a characteristic of the exposed elements or societies and its adaptive capacity to deal with and respond to the risk and stressor diseases [10]. Risk classification is not only to define the areas where may be of high risk, but also to provide useful information for management along with the supply chain to take immediate action to lessen vulnerabilities [11]. It is important to define a set of indicators for the assessment. We proposed an assessment framework consisting of 10 involving indicators that are organized into two groups (A) environmental indicators and (B) adaptive capacity indicators. Group A includes five indicators: *precipitation* (A_1), *land use/land cover (LULC)* (A_2), *LST* (A_3), *Normalized Difference Vegetation Index (NDVI)* (A_4), and *DEM* (A_5). Group B consists of five indicators including *income* (B_1), *education* (B_2), *poverty* (B_3), *housing condition* (B_4), and *population density* (B_5). Inputs for group $A_{(i)}$ are mainly derived from MODIS products, which can be downloaded from the website of NASA (https://search.earthdata.nasa.gov). Inputs of group $B_{(i)}$ are mainly extracted from the Statistical Yearbook (https://gso.gov.vn) and Health Statistical Yearbook of Vietnam (http://moh.gov.vn). LULC patterns are derived from MODIS MCD12Q1, which are consistently processed into 11 classes over Vietnam as shown in **Fig.1.**

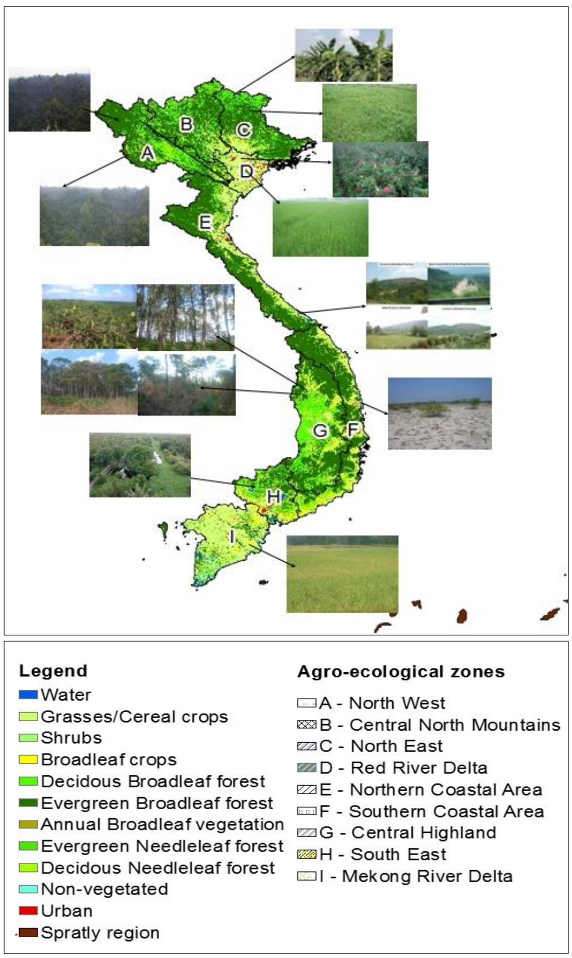

Fig. 1. Land cover and agro-ecological zones of Vietnam.

After we processed and defined the selected set of indicators, we normalized their actual values to relative positions ranging between 0 and 1. Additionally, we assume that all indicators are of equal importance and thus we used equally linear weighted overlay method. All values of indicators are aggregated and normalized again to form a *malaria risk (MR)* with a range between 0 and 1, with 1 representing the highest level of risk in such environmental and adaptive capacity conditions (*eq.1*).

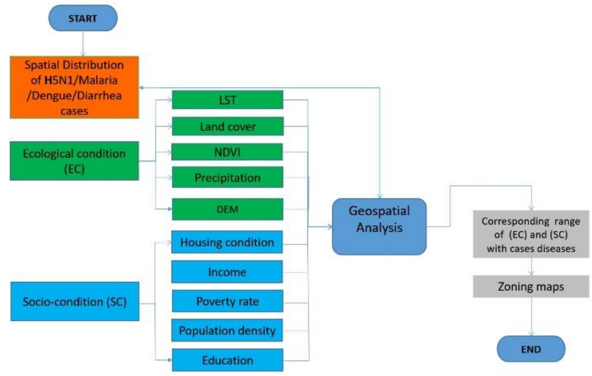

Fig. 2. Workflow of vector-borne disease assessment.

$$MR = \sum\nolimits_{Normalized}(A_{1-5}, B_{1-5}),\ \{MR(x): x = [0, 1]\} \quad (1)$$

Un-weighted quantitative aggregation and indicator standardization (in range between 0 and 1) is a common approach [11] and promoted in indicator composition [12] in particular for the risk assessment that is of no specific rule for a set of indicators.

3. RESULTS AND DISCUSSION

3.1. Assessment indicators

Environmental indicators

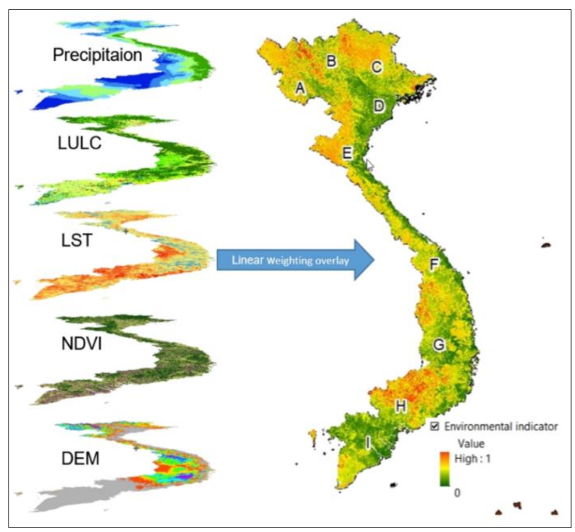

Fig. 3. Environmental indicator.

In general, an environmental indicator is aggregated with a resolution of 250 meters and high risk exhibits in the North, Central Highland, and Southern East of the study area (**Fig. 3**). These areas appear as a high rate of precipitation and land types are natural forest and planted forest. Society's ability factors inevitably play a key role in response and adaption to the risk. The poor and low-income people are likely to be in risk because of their lack of finance to access to the information resources and medical care. Similarly, low-educated individuals of societies are likely of the most vulnerability to the health risk in terms of understanding the relationship between physical and biochemical environment and infectious diseases and awareness of potential dangers from the weather extremes. Furthermore, low-education is closely related to poverty. Housing condition is a decided factor that can make members to be affected by diseases (such as good living environment for mosquitoes and insects, and lack of access to clean water supply system, higher rate to be bitten by mosquitoes, etc.).

Fig. 4 provides adaptive capacity of Vietnam based on the abovementioned factors. It can be clearly seen that low ability to respond and adapt to the risk is located in the North and Central coastal regions.

Adaptive capacity indicators

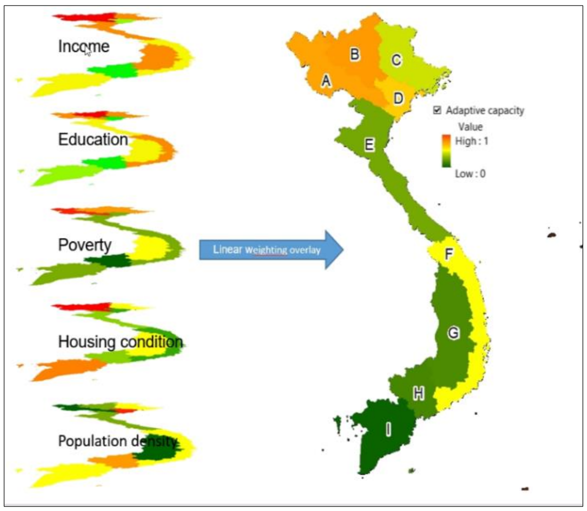

Fig. 4. Adaptive capacity indicators.

3.2. Malaria risk map

The Malaria potential map shows that Malaria significantly spreads in the Northwest region, Northern coastal region, Central North Mountains, and Central Highland of Vietnam. Ecologically speaking, these areas are characterized by a high rate of precipitation and high elevation and temperate in the range of 22-36 degrees °C with surface mainly covered by dense forest and crop as seen from distribution of landcover map (**Fig. 7).** In terms of economics, these regions are of low-income and poor housing conditions. Climatically speaking, more efforts should be paid on analyzing seasonal changes of ecological conditions associated with time-series observed cases that must be further conducted in order to obtain the trend about seasonal condition of disease cases with transmission.

Note that it is difficult to obtain the exact number of cases attacked by Malaria in Vietnam because there might be cases not registered to the hospitals. We only processed data (**Fig. 6**) based on Health Statistical Yearbook to make a comparison with our result as seen in **Fig. 8.** In general, patterns of malaria in potential maps are consistent with the observed cases in 2015.

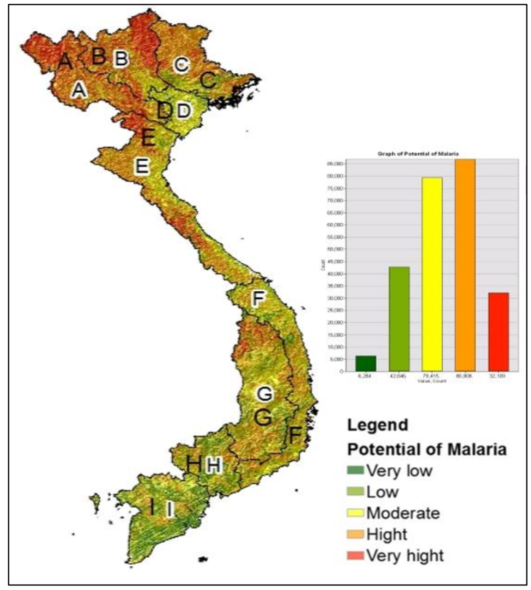

Fig. 5. Classified malaria risk map.

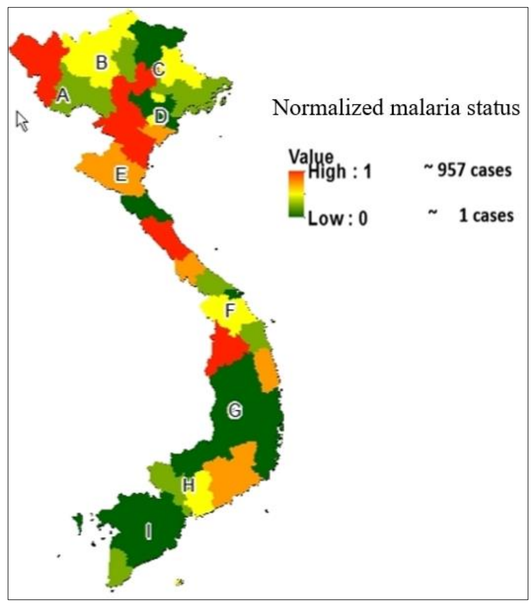

Fig. 6. Inventory Malaria in Vietnam.

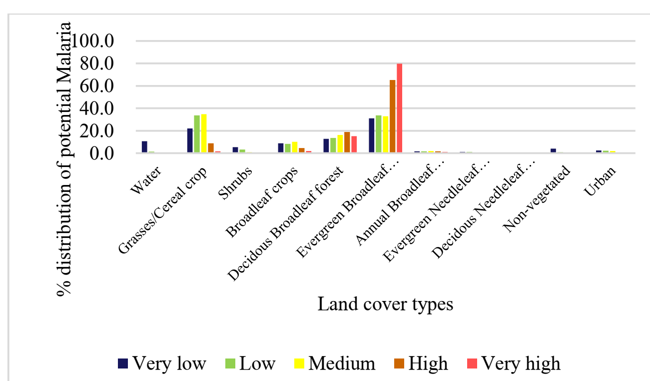

Fig. 7. Spatial analysis patterns malaria based on LULC.

However, due to the inadequate *in situ* data, the potential malaria patterns are underestimated as compared with the number of observed cases.

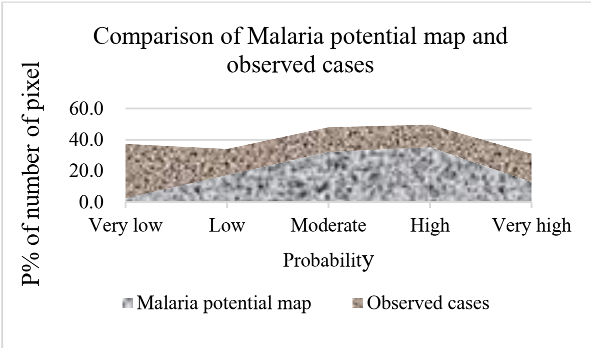

Fig.8. Malaria risk map and observed cases.

4. CONCLUSION AND SUGGESTION

In this study, we introduced an approach to assess risk of infectious diseases and applied the framework for malaria cases at national level in Vietnam by integrating environmental and adaptive capacity indicators. There are certain uncertainties remaining in our assessment so that, in the next study, high-resolution satellite images coupled with long-term observed cases data should be used in order to derive more detail forest and crop types related to vector-borne diseases, because man - made ecological transformations, such as deforestation and land use changes through agricultural practices. Urbanization with rapid development of infrastructure and continued degradation of the natural space and environment caused fragmentation of habitats and alteration of existing vector-host-parasite relationships, especially for those diseases transmitted by mosquitoes. To recap, both human-made and natural processes have contributed to changes in environment. As a result, these changes enrich ecological conditions favorable for mosquitos and insects to develop and pose public health concerns. If spatiotemporal and seasonal climatic variables coupled with land surface parameters corresponding to patterns of infectious diseases can be discovered, more tailored clinical preparedness plans will be possible, including preventive measures, effective allocation of medical and human resources, and provision of education programs.

5. ACKNOWLEDGMENT

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