

Application of Remotely-sensed Data for Modeling Malaria Infection in Lokoja, Nigeria

ABSTRACT

Aims: To estimate incidences of malaria infection in an urban setting using Remotely sensed data and matching same with hospital records to validate the use of Remote sensing data as a methodology for studying the prevalence of malaria.

Study design: Analyses of 2006 Nigerialsat-1 and Landsat ETM+ satellite data for modeling malaria infection.

Place and Duration of Study: Lokoja, Capital city of Kogi State in Central Nigeria, between March 2012 and January 2013.

Methodology: Extraction of land use types, NDVI and LST maps using ILWIS 3.3 and Idrisi software. Cross tabulation of extracted maps to carry out correlational analyses while buffer analysis was conducted to ascertain risk zones of malaria infection in the town. The clinical data was used in determining the recorded incidence of malaria in the study area.

Results: Built-up area, sand bars and vacant land occupy least land cover (i.e. 28.31%) while urban agricultural land, vegetation and water bodies covered 344.33 km² (59.72%), 41.98km² (7.28%) and 18.51km² (3.21%), respectively. The LSE value ranges from 0.92 to 0.989 with an average of 0.955 whereas the highest emissivity is recorded where vegetation is very dense and the lowest recorded for Sand bars. The LST for sand bars, vacant land and built-up area recorded the highest average temperatures of 41.13°C, 35.66°C and 34.56°C, respectively. The highest negative correlation was found in vegetation (-0.96) with other negative values recorded for urban agricultural land and water bodies. The lowest correlation (0.65) was recorded from areas covered with sand bars. The UHI map shows that temperatures at the periphery are lower (about 18°C) but higher at the core (from 26°C to 40°C).

Conclusion: The interplay of NDVI, LST and land use/cover types of Lokoja provides the impetus for the rising incidence of malaria in Lokoja town. Proper urban planning which will support proper drainages, effective waste removal, sanitary landfill sites, vegetation control, fumigation, etc. can boost sanitary conditions whilst minimizing the availability of breeding sites for mosquito larvae. At the household levels, extensive use of bed nets and periodic fumigation appear to be the most appropriate short-term measures for curtailing the incidences of malaria at the study area.

Keywords: Satellite data, land use/cover, NDVI, LST, Mosquito larvae, Malaria, Lokoja

1. INTRODUCTION

The rapid, unplanned urbanization observed in many parts of Africa is changing the context for human population and natural systems interaction [1]. The reduced vegetation cover, increased impervious surface area and the morphology of buildings in the urban centres, combines to lower evaporative cooling by storing heat during the day and releasing such during the night to warm the surface air [2]. A build-up of ambient LST in urban centres of 2^o – 3^o higher than that recorded at the surrounding suburban environment are witnessed in areas with greater vegetation cover, cultivated lands and as well as greater areas of wet soils [3; 4]. Urban topography, surface roughness, morphology of buildings and

anthropogenic activities contribute to reducing outgoing longwave radiation, hinder sensible heat loss, hinder distribution of heat and generate heat [2; 5; 6]. The increase in sensible heat flux at the expense of latent heat flux is an occurring phenomenon in urban centres and poses a great challenge to the environment and the health of the human population.

Additionally, urbanization had led to a significant alteration of local climate, and in particular creates significant heat island [7]. The urban heat island (UHI) is associated with the temperatures of central urban location rising with several degrees higher than those of nearby rural areas of similar elevation [6; 8]. Hence, different anthropogenic activities are fast becoming primary drivers of ranges of infectious diseases outbreaks and modifiers of the transmission and spatial distribution of endemic infections affecting human health [9].

An important impact of climate change encompasses induction of vector-borne, air-borne and marine-borne diseases. Diseases that are spread by mosquitoes and other insects are becoming more prevalent with warmer temperatures. Such vector borne diseases include malaria, dengue fever, yellow fever among others. The sensitivity of these vector-borne diseases to climate change depends on preceding and coexistent circumstances, such as socio-economic development, local environmental conditions, human behaviour and immunity, and the effectiveness of control measures adopted.

Rapid urbanization alters the frequency and transmission dynamics of malaria, with significant effects on the disease associated morbidity and mortality, which in turn has important implications for control [10, 11]. Keiser et al [12] reported that until recently, urban development was generally believed to reduce the risk of vector breeding, and thus malaria transmission. However, recent studies reveal that transmission and severity of malaria are influenced by the geographic characteristics of a town and by the socio-economic environment [13]. Shaman [14] emphasized that malaria is inversely associated with prosperity and development, as areas that are endemic tend to be impoverished, lacking sanitation, clean water supplies and modern construction; livestock live within villages and households and mosquito-breeding habitats abound. Malaria infections in these areas restrict economic development and widen the disparity between the developed and developing worlds. The abrupt and unplanned change in land use and human settlement patterns, poverty, urban farming, deteriorating infrastructure and overcrowding, have coincided with an upsurge of malaria and/or its vectors in Africa [15; 16; 17], in Asia [18] and in Latin America [19].

An estimated 200 million persons in sub-Saharan Africa live currently in urban centres in malaria endemic areas [13] and 24-103 million clinical attacks occur annually in those areas [12]. Donnelly et al [20] posited that malaria control strategies used in rural areas cannot be directly transferred to the urban context. The entomological profiles and clinical patterns of malaria are known to vary between urban, suburban and rural environments and transmission patterns vary greatly by city, season and age group [21].

The optimum temperature for survival of the vector lies in range of 20°C – 25°C. Malaria is caused by the species of parasites which belong to the genus *Plasmodium*. Of the four species of mosquito, *Plasmodium falciparum* is the most common species in tropical areas and the most clinically dangerous. The rainy season in Nigeria provides an excellent condition that encourages the breeding of mosquitoes and urban centres in Nigeria are endemic areas for malaria [9].

To study the complex nature of mosquito-human relationship, it is necessary to understand the modified environment that can potentially affect the dynamics of malaria diseases and the degree to which humans are interacting with the natural environment and subsequently

influencing ecological systems [1]. Therefore, this study intends to: identify the modified landscape of Lokoja; identify mosquito larvae breeding sites; estimate the LST of the land use/covers; and relate UHI to the infestation of mosquito in Lokoja.

2. MATERIAL AND METHODS

2.1 Study Area

Lokoja town lies between $7^{\circ}45'27.56''$ - $7^{\circ}51'04.34''$ N and $6^{\circ}41'55.64''$ - $6^{\circ}45'36.58''$ E, within the lower Niger trough (Figure 1). It has an estimated landmass of 63.82 sq. km and with population of 132,363 people [22] residing within the area. The population's growth rate is 2.5%. Lokoja is situated within the Guinea savanna belt witnessing the Aw type of climate. Annual rainfall is between 1016mm and 1524mm with mean annual temperature not falling below 27.7°C . The town is sandwiched to the west and east by the Patti Ridge and River Niger, respectively.

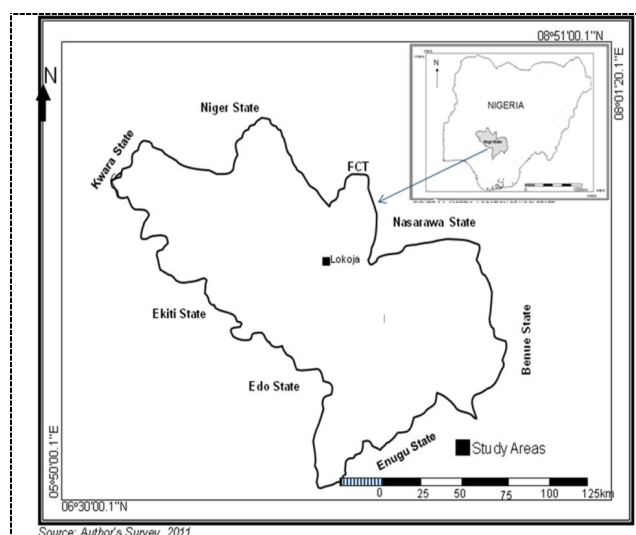


Figure 1. Location of the study area.

2.2 Materials

The main materials utilized in achieving the objectives of this study include a processed Nigerialsat-1 image of 2006 with 32m resolution, an indigenous remotely sensed data which is a combination of 3 different bands (Bands 2 (Green), 3 (Infrared) and 4 (Near Infrared)), and only the Band 6 (Thermal Infrared) of Landsat ETM+ 2006 image. Additionally, GPS Garmin 12 was used for ground truth exercise; and, clinically diagnosed malaria cases from Clinics within the study area were also used.

2.3 Methodology

ILWIS 3.3 and Idrisi software were used for the extraction of land use types, Normalised Difference Vegetation Index (NDVI) and LST. The Nigerialsat-1 data (Bands 2, 3 and 4) was used in generating the land use and NDVI maps of the area, while the Landsat Band 6 was used in extracting the LST of the area. The extracted maps were cross tabulated in determining the correlation between them while buffer analysis was also carried out in

ascertaining the risk zones of malaria infection in the town. The clinical data was used in determining the recorded incidence of malaria in the study area.

3. RESULTS AND DISCUSSION

3.1 Land use Types and Quantification

Table 1 show that the classified image of the study area has 6 distinct land uses. The built-up area which is the urban Lokoja landscape occupies about 163 km² of the entire study area (i.e. 28.31%). Sand bars and vacant land have the minimal land areas of 3.69 km² (0.64%) and 4.84 km² (0.84%) respectively, while urban agricultural land, vegetation and water bodies covered 344.33 km² (59.72%), 41.98km² (7.28%) and 18.51km² (3.21%), respectively. It also shows that urban agricultural covered more than half of the study. The initial implication of the recorded land cover (higher urban agricultural land, vegetation and water bodies) is that there is a large expanse of potential mosquito larvae breeding habitat. Mosquito larvae can effectively thrive in these land uses and their adults invade the built up area to feed and as well cause malaria infection.

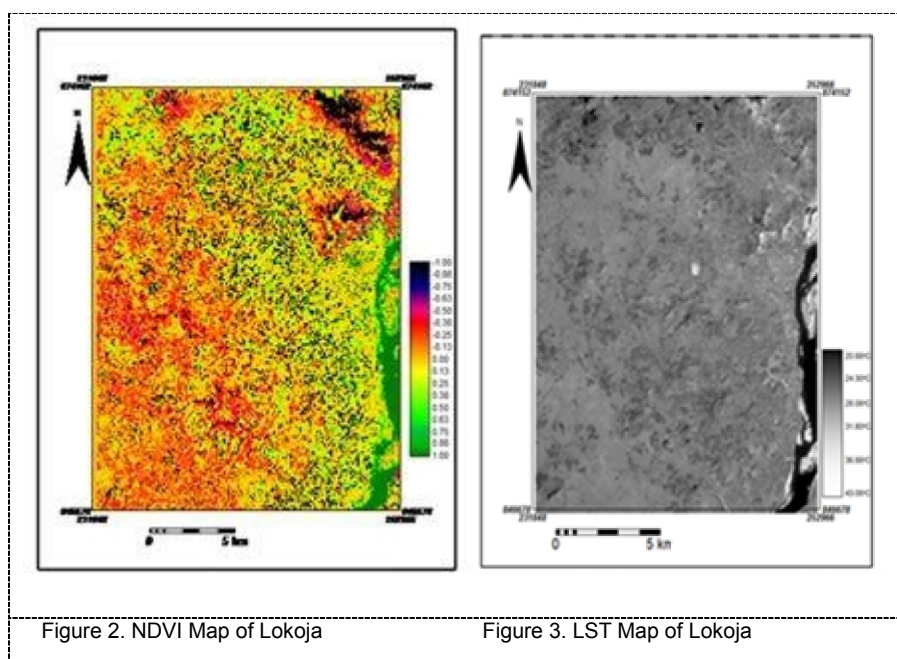
Table 1: Lokoja under different land use/cover types in 2006

Land Use/Cover Type	2006	
	Area (km ²)	%
Built-up Areas	163.2	28.3
Sand Bars	3.7	0.6
Urban Agricultural Land	344.3	59.7
Vacant Land	4.8	0.8
Vegetation	42	7.3
Water Bodies	18.5	3.2
Total	576.5	100

Source: Classified Nigériasat-1 image of 2006

3.2 NDVI, LSE and LST of Lokoja

The status of the vegetation cover is a good indicator of the prevailing climatic conditions of a particular area. Satellite remote sensing facilitates the identification of vegetation cover and the changes over time very effectively compared to the conventional field surveying techniques. The NDVI is a sensitive indicator whose values are the relative biomass and greenness of the various land use/cover types of an area. These values range between -1 and +1, serving as a good indicator of the vegetation characteristics over land surfaces. Vegetation cover over the land surface is a good indicator of the occurrence of rainfall over an area. Therefore, its values can also be used in monitoring the occurrences of rainfall at different spatio-temporal scales and also habitats of mosquito larvae. Figure 2 shows the NDVI map of Lokoja town.



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150 The land surface emissivity (LSE) value ranges from 0.92 to 0.989 with an average of 0.955

151 (Table 2). The highest emissivity is recorded where vegetation is very dense and the lowest

152 recorded for Sand bars (0.951). Table 2 also shows the derived LST as depicted in Figure 3.

153 Sand bars, vacant land and built-up area recorded the highest average temperatures of

154 41.13⁰C, 35.66⁰C and 34.56⁰C, respectively. It implies that these land use/cover types are

155 devoid of evaporating and transpiring objects and therefore may not encourage the

156 development of breeding sites for mosquitoes. But the minimum temperature recorded by

157 built-up area may suggest the heterogeneity in urban landscape as certain areas may be

158 landscaped while others are littered with wastes. Such spots are potential breeding sites for

159 mosquitoes. This is the characteristics of the Lokoja urban core.

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Table 2: LandSat ETM+ 2006 derived LSE and LST for different land use/cover types

Land use/cover	LSE			LST (⁰ C)		
	Min	Max	Avg	Min	Max	Avg
Vacant Land	0.920	0.981	0.951	28.28	43.03	35.66
Built-up Area	0.924	0.983	0.954	26.34	42.78	34.56
Urban Agric. Land	0.922	0.985	0.954	21.80	31.45	26.63
Vegetation	0.920	0.99	0.955	20.55	28.01	24.28
Water bodies	0.924	0.981	0.953	22.41	27.03	24.72
Sand Bars	0.915	0.94	0.927	39.21	43.05	41.13
Total LST					186.98	
Average LST					31.16	

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162 Vegetation, water bodies and urban agriculture area are having the least average LST

163 (24.28⁰C, 24.72⁰C and 26.63⁰C, respectively). This is as a result of the evaporating and

164 transpiring potentials of the components of these land use/cover types and their trapped

165 moisture content which collectively and ultimately facilitates the development of mosquito

166 habitats. Therefore, vegetation cover and water bodies have a strong affinity to attract

167 insects, especially mosquitoes. This is a major characteristic exhibited by the peripheral
168 areas outside the core of urban centres as confirmed by [23].

171 **3.3 Correlational Analyses**

173 Results presented on Table 3 and mapped in Figure 4 reveal correlation and regression
174 analysis between LST and NDVI for 6 different land use/cover types adopted for the study.
175 The highest negative correlation was found in vegetation (-0.96) while the lowest correlation
176 (0.65) was recorded from areas covered with sand bars. The results also revealed that
177 vegetation, water bodies and urban agriculture land show the lowest temperature and the
178 highest NDVI: this could be attributed to the fact that the increase in green biomass is often
179 associated with a reduction in surface resistance to evapotranspiration, greater transpiration
180 and larger latent heat transfer resulting to lower surface temperature which as well
181 encourages the breeding of mosquitoes within the surroundings.

Table 3: Correlation Analysis of NDVI and LST against Land use types

Land use type	Regression Equation	R	R ²
Built Up	$Y = -0.1540x_1 + 0.3538x_2 + 331.4$	0.79	0.62
Sand Bars	$Y = -0.0932x_1 + 0.4011x_2 + 325.2$	0.65	0.42
Urban Agric. Land	$Y = -0.6554x_1 - 0.0721x_2 + 310.4$	-0.91	0.82
Vacant land	$Y = -0.1087x_1 + 0.6001x_2 + 317.5$	0.71	0.50
Vegetation	$Y = -0.0548x_1 - 0.2910x_2 + 324.3$	-0.96	0.92
Water bodies	$Y = -0.1019x_1 - 0.0628x_2 + 306.1$	-0.95	0.90

Source: Author's computation (2008)

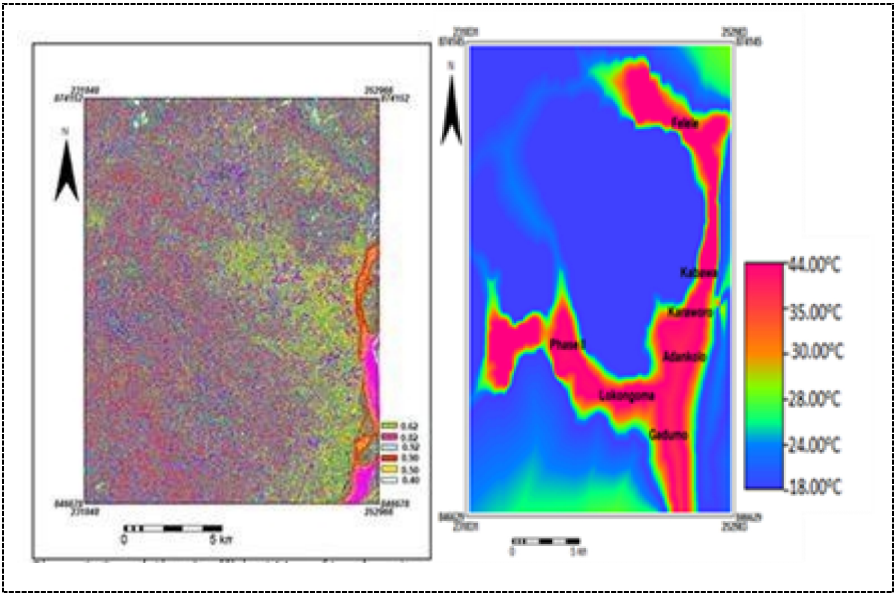


Figure 4. Correlation coefficient Map of Lokoja.

Figure 5. UHI Map of Lokoja

187 At 0 to 1.2 km where the temperatures are minimal (18°C) and on the increase to about
188 25°C, socio-economic and ecological variables (water sources and storage facilities, housing
189 characteristics, bed net usage, dumpsites, water bodies, vegetation and agricultural fields)
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provide the environment for the development and breeding of mosquito larvae. As one move inward into the town, the temperature increases between 1.2km and 1.5km which is within the flying distance of the adult mosquitoes for blood feeding. At the extremes which are the fringes of the town, temperatures are lower (18⁰C) and serve as a potential breeding sites for the mosquito, while the core of the town show a higher temperature regime from 26⁰C to 44⁰C. This confirms the results obtained by [24]. The implication is that at the two extremes the temperatures are conducive for the mosquito development and at the core where the population resides is conducive for feeding. Therefore, the UHI effect of Lokoja town (Figure 5) encourages the breeding and feeding of mosquitoes which in turn is responsible for the high incidence of malaria in the town [25; 26; 27].

3.4 Malaria Incidence in Lokoja

The incidence rate of malaria among the population of Lokoja town showed that 10,797 malaria cases were reported in the year 2006 (combination of in-patient and out-patient) in the various health centres within the study area (Table 4).

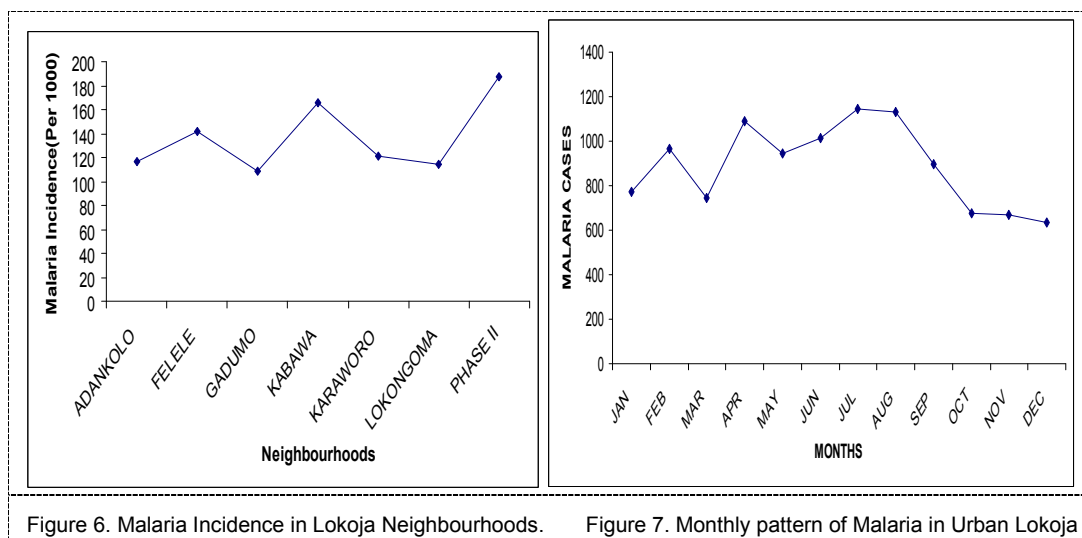
Table 1: Malaria Incidence in the Neighbourhoods of Urban Lokoja

Neighbourhoods	Population*	Malaria Cases	Malaria Incidence Per Thousand Population ('000)/Yr
Adankolo	11,812	1382 (12.8%)	117.00
Felele	11,187	1590 (14.6%)	142.13
Gadumo	10,235	1110 (10.3%)	108.45
Kabawa	12,456	2062 (19.1%)	165.54
Karaworo	11,153	1348 (12.5%)	120.86
Lokongoma	11,345	1291 (12.0%)	113.79
Phase I	10,756	2014 (18.7%)	187.24
Total	78,944	10,797 (100%)	136.13

* Population of Districts from 1991 Census Data

The distribution of malaria cases along neighbourhood line (Figure 6) showed that degree of homogeneity is higher as the values do not vary significantly. However, Kabawa and Phase I neighborhoods showed higher values of 19.1% (2062) and 18.7% (2014) of the reported malaria cases, respectively. The incidence rate was 136/1000 person per annum: with 3 neighborhoods having higher than the overall average (Felele (142/1000 person p.a.; Kabawa 165/1000 person p.a.; and Phase II 187/1000 person p.a.). Above all, these rates are greater than the global malaria incidence rate of 23.6/1000 persons p.a. for settlements [28]. This is an indication that Lokoja town is within malaria high risk areas of Nigeria.

The monthly pattern (Figure 7) showed that there was increase in malaria cases in the month of February over January. A decline was recorded in the month of March and then it increased again in April and subsequently maintained a higher level in the preceding months but however declined again after the month of August to its minimum in the month of December. This pattern correlates with the two seasons of the year (wet and dry seasons). The months of April, May, June, July, August and September are rainy months where relative humidity and rainfall amount are higher and temperature is most suitable for the breeding of mosquitoes. It is therefore, not unexpected that these months recorded high rates of malaria cases in Lokoja.



4. CONCLUSION

The ecological implication of the UHI effect on the environment of Lokoja is quite enormous as the contrasting temperatures have effect not only on human discomfort as a result of heat only but the resulting increasing heat in the core areas of the town encourages feeding by mosquitoes while the lower temperatures at the periphery provide conducive habitat for development of mosquito larvae. The interplay of NDVI, LST and land use/cover types of Lokoja provides the impetus for the rising incidence of malaria in Lokoja town. Proper urban planning that supports proper drainages, effective waste removal, sanitary landfill sites, etc. can boost sanitary conditions whilst minimizing the availability of breeding sites for mosquito larvae. The extensive use of bed nets and periodic fumigation appear to be the most appropriate short-term measures for curtailing the incidences of malaria at the study area. A much longer term planning would involve measures instituted to bring recession to the rapidly advancing changes in local-/micro-climates which in the case of Lokoja results in contrasting regimes of temperatures at the periphery and core of the town which in turn favours breeding (on the periphery) and feeding environment (at the core) for mosquitoes.

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263 **COMPETING INTERESTS**

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265 Authors have declared that no competing interests exist.

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267 **AUTHORS' CONTRIBUTIONS**

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269 'Author OOI' designed the study, and wrote the protocol. Author FU wrote the first draft of
270 the manuscript, managed the analyses of the study and the literature searches. All authors
271 read and approved the final manuscript.

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