Dear Sir:

In a letter published in this issue, Hay and Tatem raise several points regarding the use of remote sensing (RS) in two of our papers that focused on urban malaria in Africa.\textsuperscript{1,2} We appreciate the points raised by Hay and Tatem and the opportunity provided by the editor of the American Journal of Tropical Medicine and Hygiene to respond to them.

With regard to our first paper,\textsuperscript{1} it was pointed out that optical sensors should not be the only approach used for water-body discrimination and that synthetic aperture radar (SAR) imagery affords significant advantages. We agree that optical sensors have limitations, particularly due to cloud cover. However, SAR imagery does not solve all the problems. Analysis of a multi-sensor approach\textsuperscript{3} combining optical (Landsat\textsuperscript{TM}, 30 meters) and microwave (Japanese Earth Resource Satellite- JERS-1–18 meters, and European Remote Sensing Satellite ERS-1–26, 1–25 meters) data concluded that 1) SAR did a poor job in separating vegetation classes, but improved the identification of standing and flowing water; 2) urban image classification using only optical data resulted in overestimation of built-up areas; 3) the use of only microwave data for land cover/land use classification was inadequate; and 4) the multi-sensor approach resulted in accurate classification of the urban scene. Current SAR systems (10–40 meters) are too coarse for monitoring urban expansion and identifying potential larval and mosquito habitats, which were our primary concerns. Synthetic aperture radar imagery with a spatial resolution of 1 meter will be available for the first time via the TerraSAR-X radar satellite to be launched in 2006 (Spot Image http://www.spotimage.fr/html/167_240_570_684_.php). At that time, it would be desirable to adopt a multi-sensor surveillance strategy for the applications we discussed.\textsuperscript{1}

Additionally, we agree with Hay and Tatem that not all RS in urban areas is, or should be, focused on facilitating identification of larval habitats for operational staff. The RS data with different spatial resolution answer a myriad of questions and needs to be incorporated into strategies for disease control at distinct decision-making levels.\textsuperscript{4–7} Indeed, the Mapping Malaria Risk in Africa\textsuperscript{8} initiative is an excellent example of the importance of coarser spatial resolution for district, national, and global level analysis. At the coarser scales, an average risk, influenced by environmental factors, can be appraised. However, local specificities, which have the potential for improving surveillance and control efforts, are overlooked. For malaria control in Dar es Salaam and a diversity of other urban planning situations,\textsuperscript{9–11} high spatial resolution is necessary. For the landscapes in Dar es Salaam, initial evaluations\textsuperscript{12} show that a resolution >8 meters would fail to identify multiple important features.

In view of the points raised in the letter by Hay and Tatem and a recent misinterpretation of Hay and others\textsuperscript{13} regarding our second paper,\textsuperscript{2} it is important to clarify the following issues. First and foremost, our estimates of malaria incidence among urban dwellers in Africa were not derived from urban surface estimates. We used urban population estimates from the United Nations.\textsuperscript{14} We then calculated the annual number of malaria cases in urban Africa using the estimated log linear relationship between the entomologic inoculation rate (EIR) and malaria incidence. The EIRs were assigned on the basis of a three-division stratification system for urban environments.\textsuperscript{9–11} A second point concerns the role of nighttime satellite imagery\textsuperscript{15} as part of a strategy for estimating the size of urban areas. In this regard, it is important to note that there is no gold standard for even defining what is meant by urban, making cross-country comparisons on the extend of urban areas or estimates of the total urban area difficult.\textsuperscript{16} Minimal population sizes to qualify an area as urban can be as low as 2,000 (Benin) or 10,000 (Angola). While several Asian cities have tight city boundaries (e.g., Bangkok, Jakarta, or Manila) and are actually much larger than their recorded sizes,\textsuperscript{16} in Africa a large fraction of the area within administrative city boundaries is not densely populated or built up. Urban agriculture is a common phenomenon. For example, in Kampala,
Uganda, 56% of the official city area is devoted to agriculture. Thus, estimates of the size of urban areas will depend on which individual or combination of data source is used.

We agree with Hay and Tatem that bright nighttime lights may overestimate city sizes due to blooming. The most common approach to minimize this problem is the thresholding technique. Although this method shows good results for the United States, it is uncertain how big the threshold should be for less developed countries. For example, with the exception of urban areas in South Africa and Zimbabwe, most urban areas in sub-Saharan Africa have electrification levels <30% (e.g., Ethiopia = 12.9%). The annual electricity consumption per capita is, on average, only 21 kilowatt hours in Ethiopia compared to 24,248 kilowatt hours in Norway. For example, a threshold of 40% resulted in a minimum detectable population of 8,308 in Tanzania and 6,088 in Kenya. Considering that the thresholding technique eliminates night lights from small urbanized areas, but also from areas that were affected by black outs or that did not have a large percentage of cloud-free observations, we used raw data, rather then the thresholded data. Since many people in sub-Saharan Africa do not have electricity, even in and around the cities, we chose a correction factor of 2–3, which yielded a final estimate of 1.7–2.6% of urban area for Africa. We hope that others will take up the challenge of urban area estimation in Africa and improve upon our methods and estimates.

REFERENCES