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Prediction model for cyanide soil pollution in artisanal gold mining area by using logistic regression

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ABSTRACT

It has been reported that persistent cyanide pollution occurs in artisanal small-scale gold mining (ASGM)-affected catchment areas in Burkina Faso. In the present study, the logistic regression method was employed to identify the factors that influence the spatial distribution of cyanide pollution as well as to predict the cyanide pollution map risk at catchment level. Soil samples were collected from two ASGM sites in the northern Zougnazagmiline ("North") site and southern Galgouli ("South") site parts of Burkina Faso, covering areas of 22 km^2 and 20 km^2, respectively. Free cyanide concentration in each sample was measured. It was shown that the spatial distribution of cyanide was solely controlled by the soil type in Zougnazagmiline and both the soil type and electric conductivity in Galgouli. On the other hand, the cyanidation zones within the two catchments were the places where the highest risk of cyanide pollution occurs, with probabilities of 0.8 and 1 in Zougnazagmiline and Galgouli, respectively. > 20% of the settled area in the Zougnazagmiline and 5% of that in Galgouli were exposed to cyanide pollution. Logistic regression was able to reliably predict cyanide contamination in areas affected by ASGM. The model could be useful for decision-makers to plan ASGM-site decontamination.

1. Introduction

Artisanal and small-scale gold mining (ASGM) has been widespread throughout the world for over 2000 years (Hilson, 2002; Weng et al., 2014), and more developed since the mid-1980s in West Africa, including Burkina Faso (Butaré and Keita, 2009; Grätz, 2009). In 2004, between 10% and 15% of the gold mined in the world has been provided from ASGM (Adler et al., 2013; Grimaldi et al., 2015; Street et al., 2013; Telmer and Veiga, 2008). In Burkina Faso, small-scale artisanal miners produced approximately 12 tons of gold compared to an output of 14 tons from large-scale mines between 1986 and 1997 (Gajigo et al., 2012; Guèye, 2001).

The ASGM sector provides a livelihood for millions of people throughout the world (Siegel and Veiga, 2009; Weng et al., 2014). In the case of sub-Saharan Africa, at least two million people are directly employed in ASGM, and an additional 10 million more people depend on the sector for their survival (Adler et al., 2013; Chupezi et al., 2009; Hilson, 2009; Janneh and Ping, 2011; Schure et al., 2011; Weng et al., 2014). Nevertheless, several negative impacts are associated with ASGM such as an increase of infectious diseases, violence and crime, child labour and a lacking emphasis on education, loss of biodiversity and exposure of miners to strong hazardous chemicals (Adler et al., 2013). In the natural environment, ASGM induces changes to land use and landscapes, instability of the ground and landslide sand water, air and soil pollution (Adler et al., 2013; Guimaraes et al., 2011). Environmental pollution is primarily caused by the use of toxic chemical products, including cyanide, which is widely used in post-processing to extract residual gold after mercury processing. The residual material is rich in cyanide ions, which can ultimately leach into the environment without treatment or control (Adler et al., 2013; Bernstein, 2000; Sampat, 2003; Veiga et al., 2014; Velásquez-López et al., 2011).

Previous studies have shown that the main environmental parameters that control the distribution of pollutants are land cover, topography, geology, rainfall, temperature, soil type, and distance to the pollution source (Kheir et al., 2014; Venkataraman and Uddameri, 2012). In addition, several chemical parameters, such as pH, soil

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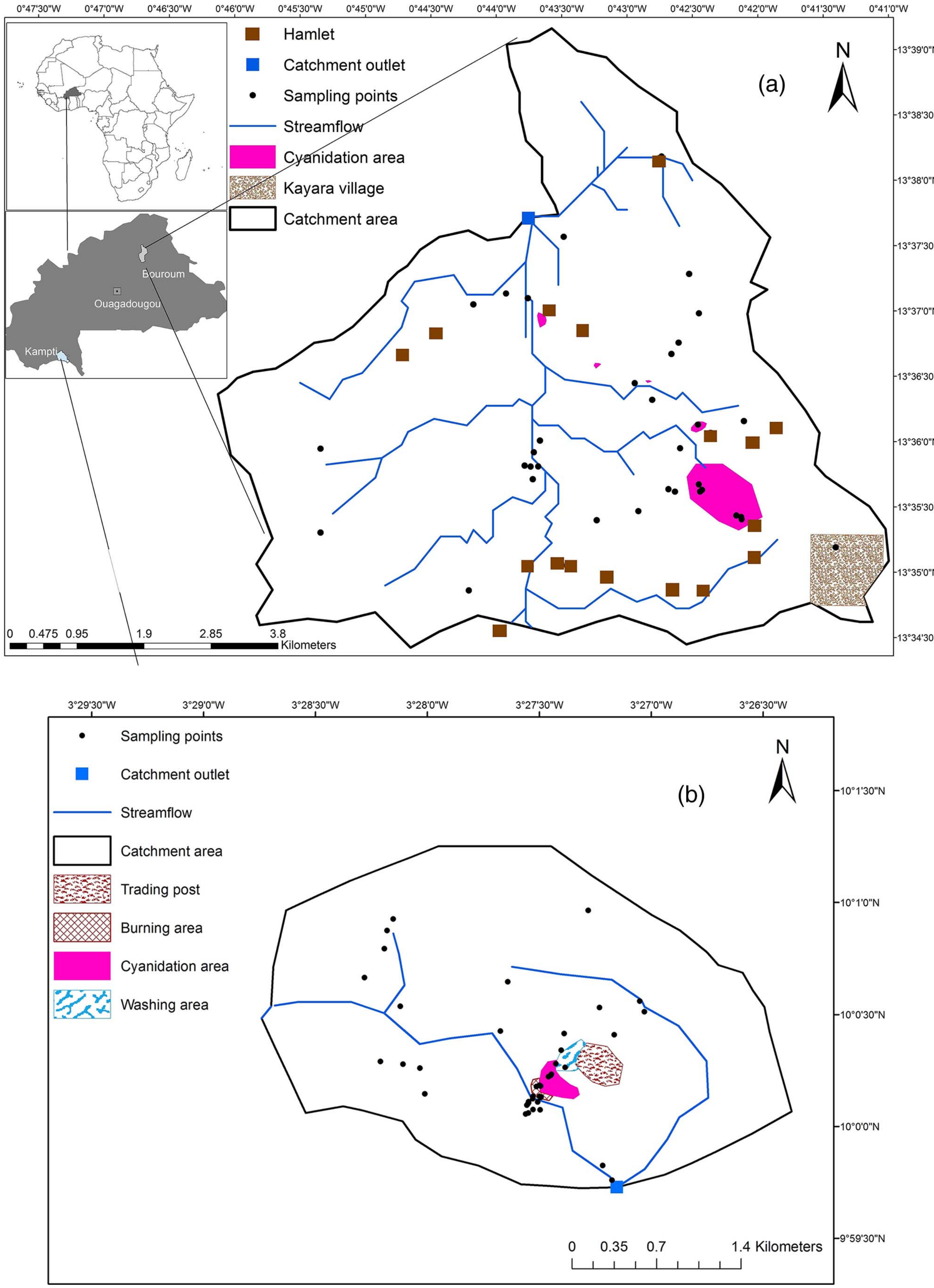

Fig. 1. Site locations (source: GLCF) and sampling points: (a) Zougnazagmiline (34 sampling sites for each year: 2015 and 2016), (b) Galgouli (39 sampling sites for each year: 2015 and 2016).