Applied Geography 62 (2015) 171–181

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Linking pesticides and human health: A geographic information system (GIS) and Landsat remote sensing method to estimate agricultural pesticide exposure

Trang VoPham [a,*], John P. Wilson [b], Darren Ruddell [b], Tarek Rashed [b], Maria M. Brooks [a], Jian-Min Yuan [a,c], Evelyn O. Talbott [a], Chung-Chou H. Chang [d], Joel L. Weissfeld [a,c]

[a] Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, 130 De Soto St, Pittsburgh, PA 15261, USA
[b] Spatial Sciences Institute, University of Southern California, 3616 Trousdale Pkwy AHF B55, Los Angeles, CA 90089, USA
[c] Division of Cancer Control and Population Sciences, University of Pittsburgh Cancer Institute, 5150 Centre Ave, Pittsburgh, PA 15232, USA
[d] Department of Medicine, University of Pittsburgh, 1218 Scaife Hall, 3550 Terrace St, Pittsburgh, PA 15261, USA

A R T I C L E I N F O

Article history:
Available online

Keywords:
Pesticide exposure
Geographic information system (GIS)
Remote sensing
Normalized Difference Vegetation Index (NDVI)
Environmental epidemiology

A B S T R A C T

Accurate pesticide exposure estimation is integral to epidemiologic studies elucidating the role of pesticides in human health. Humans can be exposed to pesticides via residential proximity to agricultural pesticide applications (drift). We present an improved geographic information system (GIS) and remote sensing method, the Landsat method, to estimate agricultural pesticide exposure through matching pesticide applications to crops classified from temporally concurrent Landsat satellite remote sensing images in California. The image classification method utilizes Normalized Difference Vegetation Index (NDVI) values in a combined maximum likelihood classification and per-field (using segments) approach. Pesticide exposure is estimated according to pesticide-treated crop fields intersecting 500 m buffers around geocoded locations (e.g., residences) in a GIS. Study results demonstrate that the Landsat method can improve GIS-based pesticide exposure estimation by matching more pesticide applications to crops (especially temporary crops) classified using temporally concurrent Landsat images compared to the standard method that relies on infrequently updated land use survey (LUS) crop data. The Landsat method can be used in epidemiologic studies to reconstruct past individual-level exposure to specific pesticides according to where individuals are located.

© 2015 Elsevier Ltd. All rights reserved.

Introduction

Pesticides, chemicals designed to treat pests such as insects, have been associated with adverse human health outcomes such as cancers (Alavanja, Hoppin, & Kamel, 2004; Blair, Ritz, Wesseling, & Beane Freeman, 2015). One source through which pesticide exposure may impact human health is via residential proximity to agricultural pesticide applications (Rull & Ritz, 2003; Ward et al., 2000). Applied pesticides may drift through the air and the ground and through post-application volatilization. Large-scale pesticide drift incidents frequently occur in agricultural areas in California (CA), United States (US), impacting residents and field workers and resulting in acute symptoms such as vomiting and impaired breathing (Harrison, 2006). In California, upwards of 90%

Abbreviations: AI, active ingredient; CA, California; CCM, compressed county mosaic; CDPR, California Department of Pesticide Regulation; CDWR, California Department of Water Resources; COST, cosine estimation of atmospheric transmittance; DNR, Department of Natural Resources; GIS, geographic information system; LUS, land use survey; MLC, maximum likelihood classification; NAD83, North American Datum 1983; NAIP, National Agriculture Imagery Program; NASA, National Aeronautics and Space Administration; NDVI, Normalized Difference Vegetation Index; NIR, near-infrared; NPS, nonpoint source; PLSS, Public Land Survey System; PUR, Pesticide Use Report; PUS, Pesticide Usage Survey; R, red (spectral band); SPOT, Satellite Pour l'Observation de la Terre; SRS, stratified random sampling; TM, Thematic Mapper; US, United States; USDA, United States Department of Agriculture; USGS, United States Geological Survey.

* Corresponding author. Present address: Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, 401 Park Dr, Boston, MA 02215, USA. Tel.: +1 757 478 2515.

E-mail addresses: vophamt@gmail.com (T. VoPham), jpwilson@dornsife.usc.edu (J.P. Wilson), druddell@usc.edu (D. Ruddell), rashed@gsareh.com (T. Rashed), brooks@edc.pitt.edu (M.M. Brooks), yuanj@upmc.edu (J.-M. Yuan), eot1@pitt.edu (E.O. Talbott), changj@pitt.edu (C.-C.H. Chang), jwepid@comcast.net (J.L. Weissfeld).

http://dx.doi.org/10.1016/j.apgeog.2015.04.009
0143-6228/© 2015 Elsevier Ltd. All rights reserved.

of registered pesticide products are prone to drift. Gunier et al. (2011) demonstrated that pesticides measured in carpet dust from 89 residences in California were significantly correlated with residential proximity to agricultural pesticide applications quantified using a geographic information system (GIS) (Spearman correlation coefficients 0.23 to 0.50; $p<0.05$). Humans are subsequently affected by pesticides through dermal contact and ingestion, especially as pesticides are less likely to degrade within houses (Gunier, Harnly, Reynolds, Hertz, & Von Behren, 2001).

Elucidating the exact role pesticide exposure may play in the risk of developing adverse health outcomes is impacted by the methods used to quantify exposure. GIS metrics can combine multiple data sources to reconstruct historical exposure to specific pesticides (Franklin & Worgan, 2005). The California Department of Pesticide Regulation (CDPR) has collected Pesticide Use Report (PUR) data pertaining to agricultural use pesticide applications since 1974, including pounds (1 pound represents 0.45 kg) of pesticides used to treat specified crop types on specified dates within Public Land Survey System (PLSS) sections (CDPR, 2014). However, PUR data alone cannot be used to match pesticide applications to specific geographic locations at a scale finer than the 2.59 km^2 (1 mi^2) PLSS section level. This limitation has motivated attempts to combine PURs with land use data, notably the California Department of Water Resources (CDWR) land use surveys (LUS's). Rull and Ritz (2003) developed the standard validated GIS method of estimating agricultural pesticide exposure in California via a three-tier methodology that assigns PUR pounds of applied pesticides to LUS crop fields (Rull, Ritz, & Shaw, 2006a, 2006b). The notion of "tiers" refers to the level of certainty with which a PUR pesticide application can be assigned to a particular LUS crop field. Combining PURs with a LUS enables pesticide application rate calculations at geographic scales finer than the PLSS level. However, CDWR LUS's are infrequently conducted on a county basis once every seven to 10 years, during which time significant land use changes can occur (Nuckols et al., 2007).

Although vector data have typically dominated this research, raster data provide a valuable way to incorporate temporally concurrent land use information in pesticide exposure estimation. Ward et al. (2000) pioneered the integration of Landsat remote sensing, which has continuously captured satellite imagery of the Earth since 1972 (USGS, 2014), in estimating pesticide exposure. Supervised classification of a Landsat image of Nebraska, US from 1984 was implemented to classify agricultural land cover types, which were subsequently assigned crop-specific pesticide use probabilities. Wan (2015) developed a GIS and remote sensing method to estimate population-level exposure using Nebraska land use data (classified from Landsat images), United States Geological Survey (USGS) county-level pesticide data, and crop-specific pesticide usage from farmer surveys. Population density grid cells were assigned pesticide exposure values according to downscaled pesticide data using 1,000 m radius buffers around cell centroids. Maxwell, Airola, and Nuckols (2010) demonstrated how Landsat imagery of California could be used to downscale the identification of PUR pesticide-treated crop fields below the LUS level (minimum mapping unit 0.008 km^2) (Nuckols et al., 2007). Normalized Difference Vegetation Index (NDVI) values, a measure of vegetative density, were used to classify imagery into crop fields via a minimum distance method, and when used in conjunction with PLSS sections, can identify probable crops treated with pesticides (Maxwell, 2011).

However, minimum distance classification is not widely used in practice as it cannot take into account the spectral variability present within land use classes (Campbell & Wynne, 2011). Alternative approaches include implementing per-pixel maximum likelihood classification (MLC) using NDVI values (De Wit & Clevers, 2004; Guerschman, Paruelo, Bella, Giallorenzi, & Pacin, 2003) and/or per-field classification, which is useful in addressing within-field spectral heterogeneity (Lu & Weng, 2007). For example, Turker and Ozdarici (2011) implemented per-field classification, where ML-classified pixels of SPOT, IKONOS, and QuickBird imagery of Turkey in 2004 were used to classify vector fields according to the most frequently occurring land use class pixel.

This study demonstrates the use of an improved GIS and remote sensing method, the Landsat method, to estimate agricultural pesticide exposure in a year without a concurrent standard LUS crop field dataset. The Landsat method matches PUR pesticide application data to concurrent Landsat images that have been classified into crops via an MLC and per-field classification approach. Pesticide-treated crop fields intersecting 500 m buffers around geocoded locations are used to estimate pesticide exposure. Our first research objective was to execute an accuracy assessment comparing classified Landsat images in 1990 to the 1990 LUS gold standard (ground truth). As part of this first objective, we determined the accuracy of 1990 agricultural pesticide exposure estimates using classified Landsat images from 1990 vs. the 1990 LUS. Our second research objective was to evaluate the crop specificity of 1985 pesticide applications matched to classified Landsat images, a demonstration of the Landsat method's utility. As part of this second objective, we compared pesticide exposure estimates derived from 1985 pesticide application data matched to classified Landsat images from 1985 vs. the 1990 LUS.

Methods

Study area and data sources

Kern County, CA, US is 21,061.58 km^2 in area and is one of 19 counties in the agriculturally intensive Central Valley (Fig. 1) (USDA, 2003). Agricultural croplands are predominantly found in the central and northwestern portions of the county. From 1982 to 1992, the majority of Kern County's farm area (4,058–3,900 km^2) was associated with harvested cropland (76.6–86.7%), which was consistently dominated by cotton (34.6–36.9%) (USDA, 2014).

The CDPR PURs include California agricultural pesticide application data from 1974 to present (full use reporting started in 1990) (CDPR, 2014). PUR data include the name, pounds (1 pound represents 0.45 kg), date, crop, and PLSS section associated with reported pesticide applications. The PLSS divides portions of the US into 2.59 km^2 (1 mi^2) sections, each identified by a county, principal meridian, township, range, and section (National Atlas, 2014). USGS and National Aeronautics and Space Administration (NASA) Landsat satellites have collected Earth imagery since 1972 (USGS, 2014). The Thematic Mapper (TM) sensor onboard Landsat 4 and 5 (used in this analysis) captured seven spectral bands with at least 30 m spatial resolution. Each Landsat scene, defined by a Path–Row designation, spans 185 km and is captured every 16 days. Bands 3 (red; 0.63–0.69 μm) and 4 (near-infrared; 0.76–0.90 μm) were used in this analysis to calculate NDVI values (Maxwell, Airola, et al., 2010; Maxwell, Meliker, & Goovaerts, 2010), which harness information from wavelengths of electromagnetic radiation absorbed and reflected by green plants and their changes throughout the growing season (USGS, 2011). NDVI values range from −1 (no or sparse vegetation) to 1 (dense vegetation). The CDWR conducts LUS's of agricultural lands to monitor land use changes in California on a county basis focusing on over 70 crop types (CDWR, 2014). Each LUS dataset is updated every seven to 10 years. Residential parcels were selected from the 2012 Kern County Assessor file via use codes (e.g., 0100, single family residence) (Kern County Assessor, 2012). All administrative boundaries were mapped

Download English Version:

https://daneshyari.com/en/article/6538504

Download Persian Version:

https://daneshyari.com/article/6538504

Daneshyari.com