USING PHYSICAL PARAMETERS AND GEOGRAPHIC INFORMATION SYSTEM ANALYSES TO PREDICT POTENTIAL RIPARIAN RESTORATION SITES FOR GIANT CANE IN SOUTHERN ILLINOIS

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Abstract.—Riparian buffers have been widely advocated as a best management practice for improving stream and lake water quality. Giant cane (*Arundinaria gigantea*) is a good candidate to include in multispecies riparian buffers designs, as it promotes infiltration of surface runoff and deposition of sediment and associated nutrients. To examine the potential of giant cane as a riparian zone species in the Cache River watershed in southern Illinois, we identified common physical site characteristics for 140 existing southern Illinois canebrakes. Percent slope, soil taxonomy, and pH, along with digital elevation models and land cover mapped with geographic information systems, were used to determine the potential suitability of sites within the watershed for canebrake plantings and general riparian restoration. The following soil characteristics were determined to be associated with giant cane success: percentage of area containing slopes of ≤3 percent, fine to coarse-silty textures, pH of 5.3-6.7, effective cation exchange capacity of <30 units, available water holding capacity ≥0.12, bulk density of 1.37-1.65 g/cm^3, and percent clay of 11-55. Eighty percent of existing giant cane sites were found within these slope and soil characteristics. The total area of potential riparian canebrake landscapes based on these parameters is 7,470 ha within the Cache River watershed.

INTRODUCTION

Giant cane (*Arundinaria gigantea*) was historically a dominant component of riparian areas in the lower midwestern and southeastern United States, including southern Illinois (Brantley and Platt 2001, Platt and Brantley 1997, Platt et al. 2009). Today, giant cane occupies only 2 percent of its historical range and is listed as a "critically endangered" species due to factors such as overgrazing by domestic livestock, altered fire regimes, agricultural land clearing, and flood control projects (Brantley and Platt 2001, Noss et al. 1995). Cane is a native bamboo species with a relatively dense rooting network that resists erosion, increases nutrient uptake, and promotes infiltration in riparian zones (Brantley and Platt 2001). Its ability to promote infiltration of surface runoff and deposition of sediment and associated nutrients through its high density culms and extensive shallow rooting network makes giant cane a good candidate to include in multispecies riparian buffer designs (Schoonover et al. 2005, 2006). Giant cane performs as well as, or better than, forest vegetation in nitrogen renovation in groundwater (Schoonover et al. 2010). It also provides significant wildlife habitat benefits, especially in the fragmented midwestern landscape (Blattel et al. 2009).

To determine where giant cane should be considered and targeted for restoration, existing stands need to be analyzed for common landscape or physical characteristics, such as soils or topography. These factors can then be used to define areas suitable for canebrake plantings and general riparian restoration. Restoration budgets are limited, so targeting species to areas where they will have the

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most success is critical for efficient use of funds. Geographic information system (GIS) and remote sensing technologies are well established as excellent tools for delineating and mapping species distributions (Boyd and Foody 2011, Franklin and Miller 2010). These geotechnology tools have been used in a variety of studies such as determining riparian restoration sites (Russell et al. 1997), tracking invasive species (Pande et al. 2007), and mapping vegetation with remote sensing (Akasheh et al. 2008).

METHODS

The Cache River watershed is classified as a hydrologic unit code 12-level basin in southern Illinois. Infrared aerial photography of the Cypress Creek Refuge and Cache River watershed was taken in March 2009 by the U.S. Fish and Wildlife Service (USFWS). The leaf-off imagery was collected by using three spectrum bands of red, green, and near-infrared at a spatial resolution of 0.21 m. Using visual interpretation of the photography, we identified the location of 140 canebrakes. Canebrakes were confirmed with groundtruthing to determine the accuracy of the interpretation process (ArcGIS Desktop: Release 9.2, Esri, Redlands, CA). Groundtruthing proved to be 100 percent accurate as the presence of giant cane was confirmed at all predicted locations.

Soil quality such as chemical composition, moisture retention capability, and texture can be used to guide water quality buffer restoration (Dosskey et al. 2006). Soil characteristics used to measure soil quality are readily available through the Soil Survey Geographic (SSURGO) database and include soil taxonomy classification, pH, bulk density (BD), available water capacity (AWC), effective cation exchange capacity (ECEC), and percent clay (PC).

The SSURGO database includes GIS polygons, referred to as map units, which are given unique keys to identify map units that have common soil characteristics. The aforementioned soil characteristics were assigned to the map units by using the Soil Data Viewer provided by the U.S. Department of Agriculture's Natural Resources Conservation Service (Natural Resources Conservation Service 1995). By assigning the map-unit key to each cane site, we were able to link the soil characteristics to each of our samples by using ArcGIS. Tabular data containing all the soil information for the cane sites were exported for further analysis.

JMP statistical software (SAS Institute Inc., Cary, NC) was used to create frequency tables of all the soil characteristics. Soil parameters were assigned based on the range and frequency of values for each soil characteristic (Table 1). Each soil parameter was then used to select SSURGO map units that were most likely to contain giant cane.

Table 1.—Parameters used to define potential giant cane soil characteristics in Cache River watershed, Illinois

	Slope (%)	Soil taxonomy	pH	ECEC (meq)	AWC	Bulk density (g/m^2)	Clay (%)
Range	0.5 - 27	Fine, fine silty, fine loamy, coarse silty, coarse loam	5.3 – 7.1	0 – 28.9	0.1 – 0.2	1.4 – 1.8	11 – 55
Parameters used in analysis	<3.0	Fine, fine silty, and coarse silty	5.3 – 6.7	<30	>0.1	1.4 - 1.7	11 – 55

In addition, proximity of the 140 canebrakes to streams and roads was determined, and JMP statistical software was used to determine correlations. Based on these correlations, only distance to streams was significant. To further delineate the potential giant cane landscapes, we created stream buffer polygons from the stream segments in ArcGIS to represent the variation in measures of distance to stream. We decided to use three different measures of distance to stream to create the stream buffer polygons. Stream segments were buffered to 50-, 100-, and 200-m polygons by using the ArcGIS line buffer tool. We then selected the overlapping areas of the soil polygons and the stream buffer polygons to create three different potential giant cane landscapes, and determined how many existing canebrakes were within each of the landscapes.

Land cover data were obtained from the 2012 cropland data layer (CDL) to determine the current land covers within potential giant cane polygons. The associated tables were exported and evaluated for percentage of land cover based on the general categories of grassland or forest, cultivated cropland, and developed land.

The three-band visual-near-infrared (VNIR) imagery collected by the USFWS provided the opportunity to also map canebrakes by using supervised image classification, a common process in image classification and species mapping (Akasheh et al. 2008, Verburg et al. 2011). Because the imagery was collected during leaf-off and cane is an evergreen species, we assumed that the cane would have a unique signature relative to the otherwise dormant vegetation. We used the image classification analysis tool in ArcMap 10.0 (Esri) to identify potential canebrakes. Supervised classification uses groundtruth data as signatures to classify remote sensing imagery. Using a hand-held global positioning system (GPS), we collected a data set of well-established canebrakes. Signatures for the image classification process were created from the data set. An iterative process using supervised classification methodologies was used to delineate the different signatures of the digital imagery.

For the first iteration, we delineated seven classifications. Classification 1 included the GPS-collected canebrake polylines to determine the canebrake signature. The second was stream polygons digitized from USFWS imagery. The other five land covers were difficult to determine because the imagery was collected in March during the leaf-off season. Therefore, we obtained land cover data from the CDL from the previous growing season to classify the other five signatures. The classifications were determined by locating individual plots of land on the imagery, then classifying them using the CDL data set. The land covers used for classification were corn, soybeans, forest, roads, and wetlands.

After creating a signature file with the seven land covers, we used a maximum likelihood classification to create a map of the seven land covers. To determine the accuracy of the classification process, we randomly selected eight of the larger clusters of cane pixels from the classified imagery which we thought would be accessible for the groundtruthing process.

Groundtruthing established that only two of the eight randomly selected clusters contained canebrakes. Four of the sites were determined to have cypress (*Taxodium distichum*) trees present; two had neither cane nor cypress. This information was used to conduct the second iteration of the classification process. Based on the groundtruthing results, we assumed that cane and cypress could possibly have similar signatures that the first iteration could not differentiate.

For the second iteration we used GPS-collected areas of cypress trees as an eighth land cover in the classification process. To further delineate cane, groundtruthed noncane areas that were classified as cane in the first iteration were also included in this iteration. It was assumed that using these two new signatures would help to establish a more distinctive signature for canebrakes. As expected, the second iteration reduced the classified cane pixels by roughly 25 percent compared to the first iteration.

To establish contiguous cane pixels and remove extraneous pixels, the output of the second iteration was processed by using the majority filter tool in ArcGIS. Pixels of cane locations were then converted to point locations to be processed with the point density tool in ArcGIS. Eighteen of the densest areas of classified cane were extracted for a second round of groundtruthing, but this second iteration did not increase the accuracy. Consequently, using remote sensing to locate canebrakes was not likely to be feasible.

RESULTS

Close to 50 percent of canebrakes were on land with less than 1-percent slope. Almost 20 percent of canebrakes were on land with a 1- to 2-percent slope. Above 2-percent slope, there was no significant difference in relative occurrence among the slopes (Figs. 1 and 2). The fewest canebrakes were located on southwest- and western-facing slopes, though there was no significant difference among the remaining aspect directions (Fig. 3). The highest number of canebrakes was found between 100 and 105 m above mean sea level (m msl) (Fig. 4). Seventy-six percent of the canebrakes grew between 95 and 110 m msl, and cane was found only between 90 and 150 m msl.

Eighty percent of canebrakes were found on silt loam soils; however, this grouping includes the soil classification Bonnie and Petrolia, which is a mixture of both silt loam and silty clay loam soils (Fig. 5). Bonnie and Petrolia soils, which constitute half of silt loam soils, occur on nearly level flood plains of 0- to 2-percent slope and occasionally on flood-plain steps. They formed in light-colored, recently deposited, acid (although less so for Petrolia), silty alluvium. These soils are classified as poorly drained and very poorly drained. Saturated hydraulic conductivity is moderately high, and permeability is moderately slow. Stream flooding occurs frequently to rarely, and occurs commonly in the winter and spring. In the undrained condition, these soils have an intermittent apparent water table from as much as 0.6 m above the surface to 0.01 m below the surface, typically between October and July. Where drained, an intermittent water table is within 0.3 m of the surface, typically between December and May. The potential for surface water runoff is low to medium (U.S. Department of Agriculture 2011).

About half of the canebrakes (48 percent) were found within 40 m of a stream, with 26 percent found within 20 m (Fig. 6). There was an equal likelihood of finding cane at any distance beyond 60 m. Fifty-five percent of sites were found within 50 m of a stream, 17 percent were located between 50 and 100 m of a stream, and 19 percent were between 100 and 200 m of a stream. However, many of these streams were ephemeral and contained water only during high runoff periods.

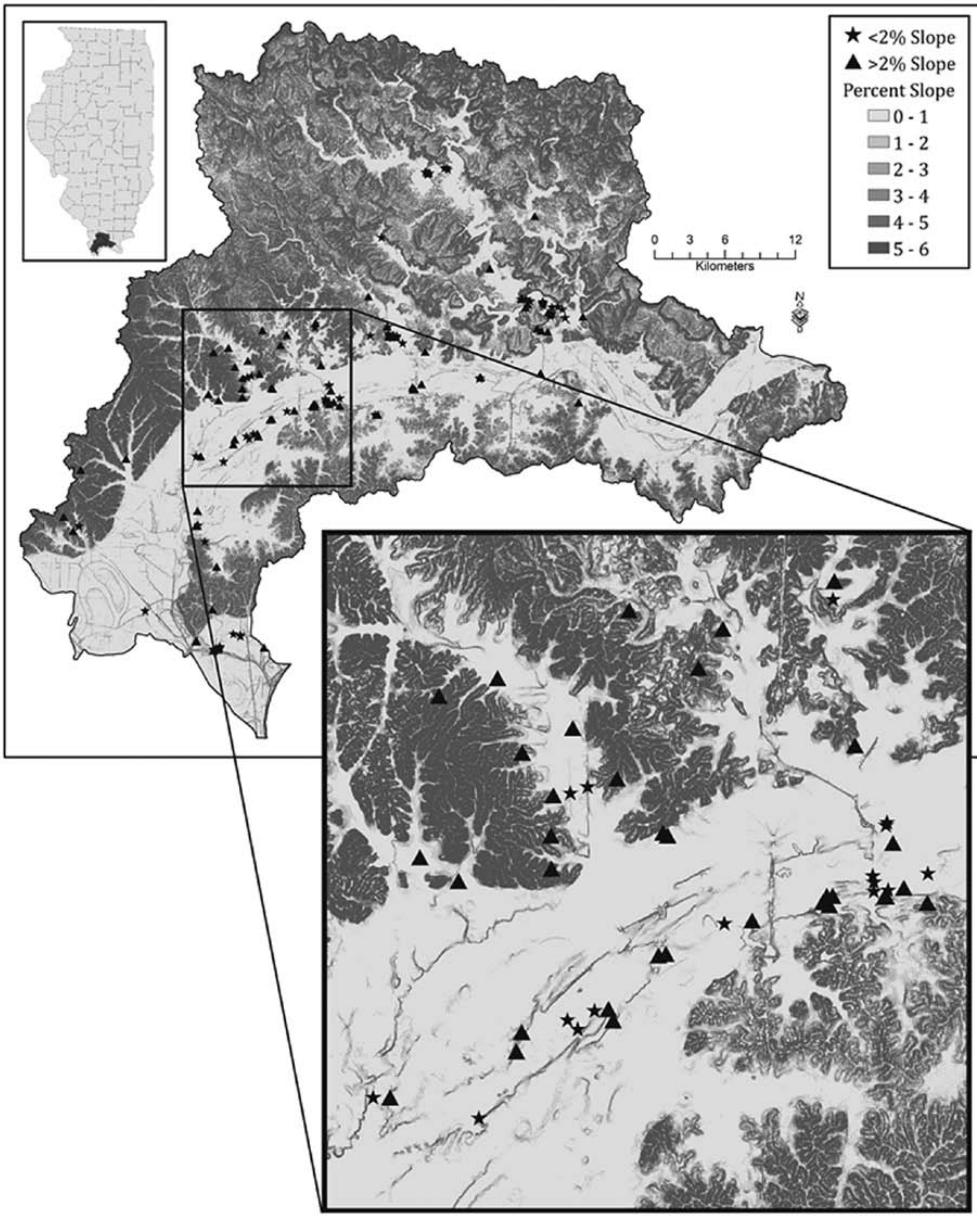

Figure 1.—Slope map of Cache River watershed, southern Illinois, with the canebrakes marked in stars. Low slope areas are marked by the darker shade.

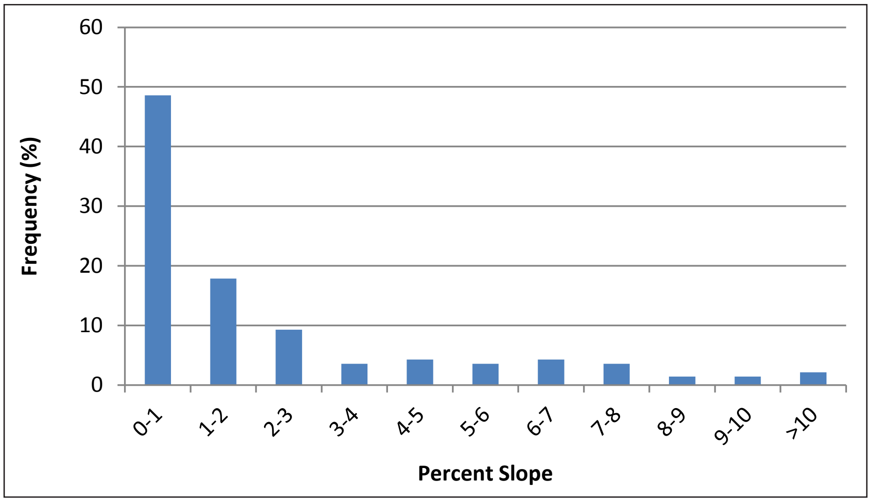

Figure 2.—Frequency of canebrake occurrence by slope class from a survey in the Cache River watershed, Illinois.

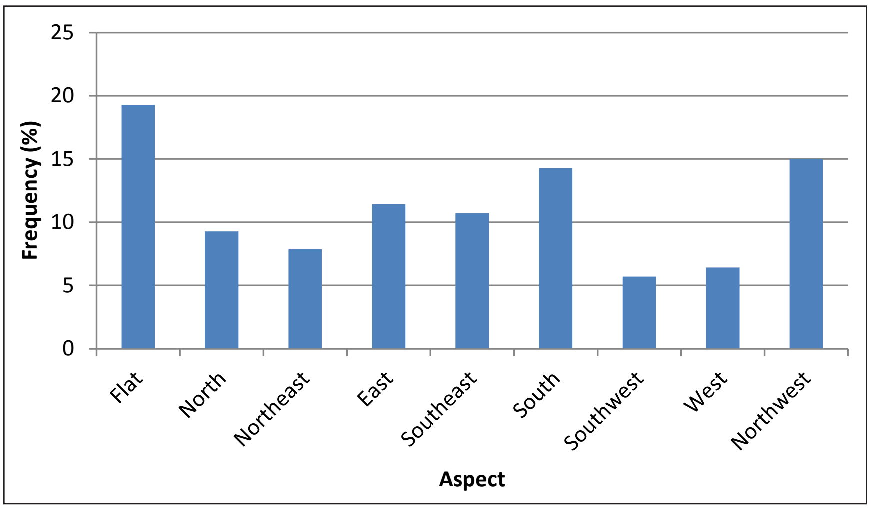

Figure 3.—Frequency of canebrake occurrence by aspect from a survey in the Cache River watershed, Illinois.

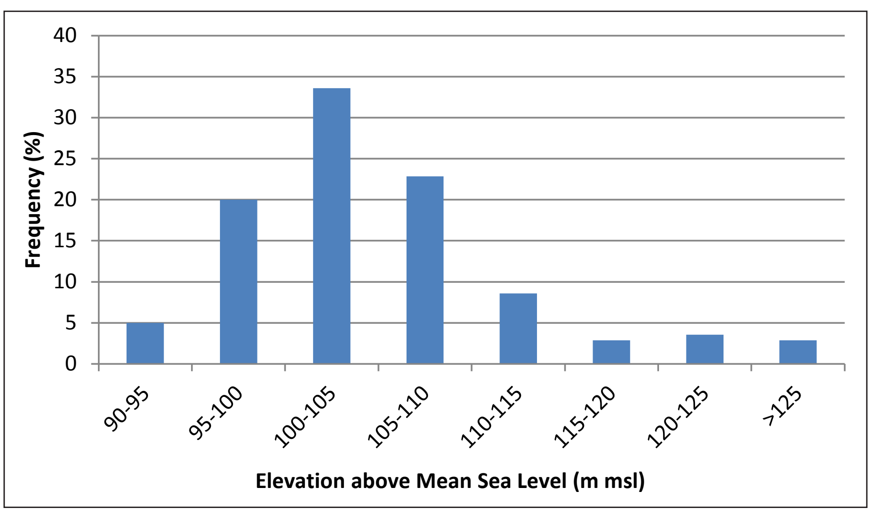

Figure 4.—Frequency of canebrake occurrence by elevation above mean sea level from a survey in the Cache River watershed, Illinois.

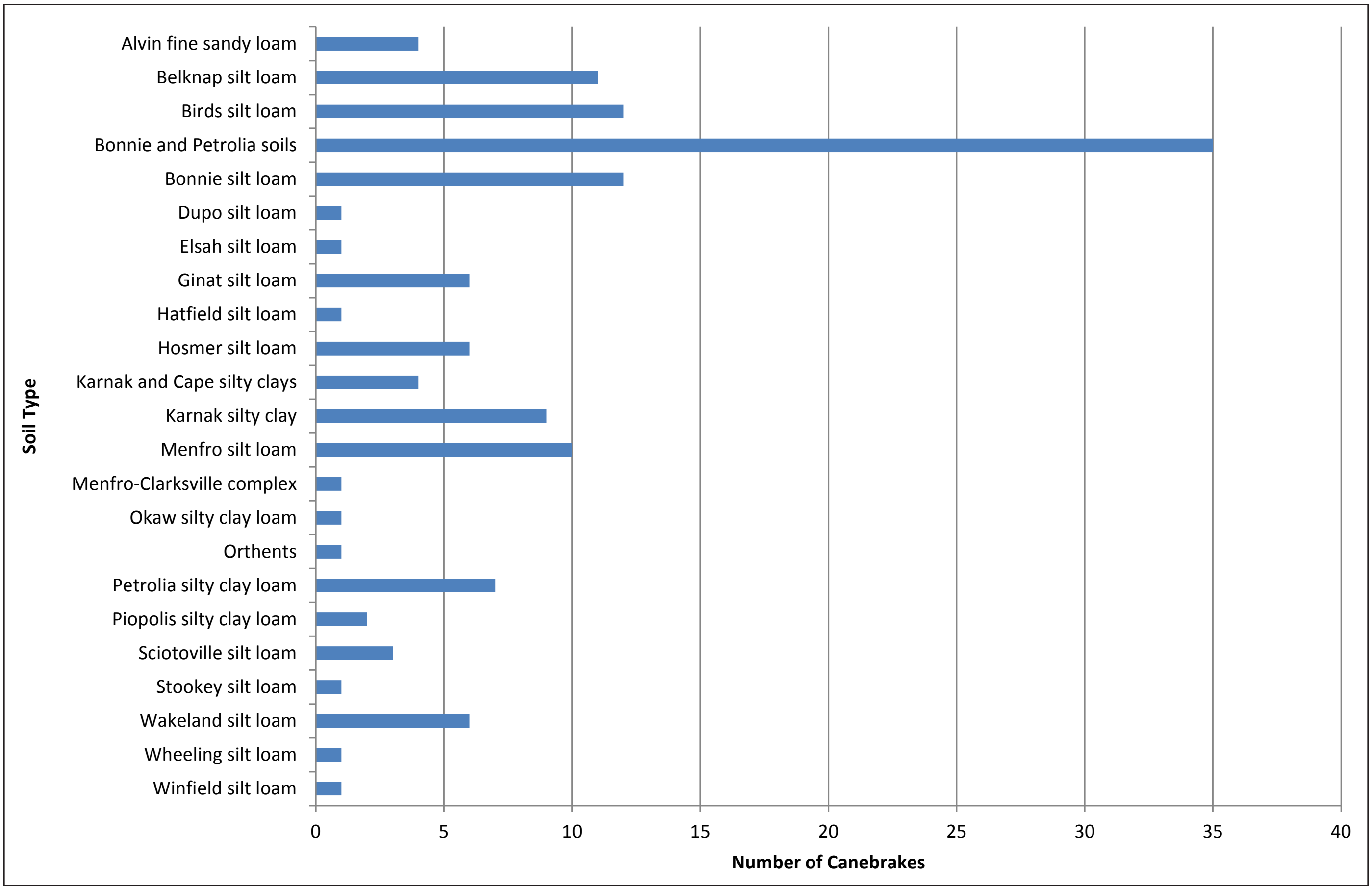

Figure 5.—Soil series within canebrakes from a survey in the Cache River watershed, Illinois.

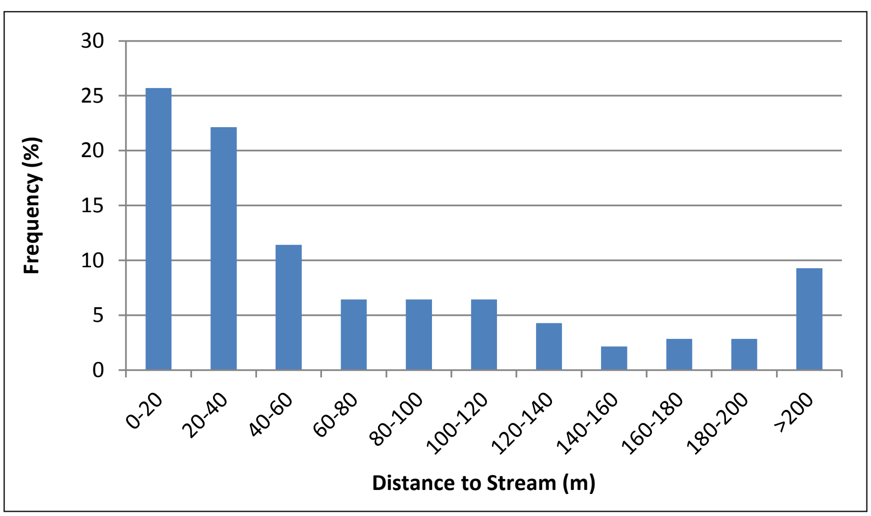

Figure 6.—Proximity of canebrakes to streams, including ephemeral channels, from a survey in the Cache River watershed, Illinois.

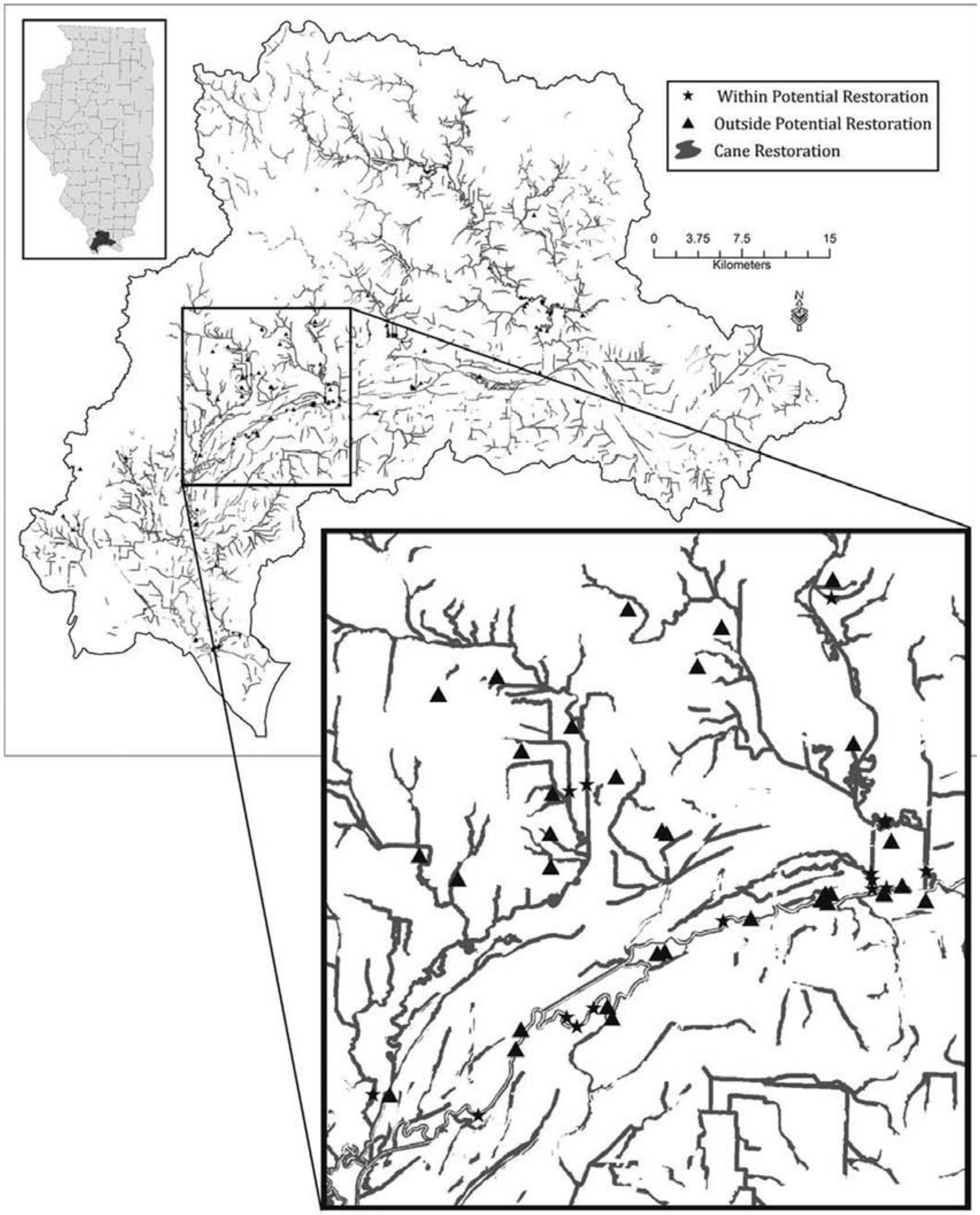

Figure 7.—The existing canebrakes within the potential giant cane landscapes, defined by a 50-m stream buffer and the soil parameters, Illinois.

The results of the spatial analysis to delineate potential areas of giant cane were mixed. When existing canebrakes were compared only to the soil polygons, slightly fewer than 80 percent of the canebrakes were found within the polygons selected by the slope and soil parameters (Fig. 7). However, that number increased to 88 percent by including cane sites within 25 m of the polygons. We made this adjustment by adding a 25-m buffer to the polygon using the ArcGIS buffer tool. This result can be explained in two ways. First, borders are placed subjectively on the SSURGO map units, where they may not correspond to specific demarcations between characteristics. Soils may change gradually rather than abruptly over the landscape, depending on topography. Second, some spatial error occurs both in placing cane site points and in GIS processing.

However, when restricting the potential cane sites further by using the 50-, 100-, and 200-m distance to stream buffers, the proportion of canebrakes within the potential sites was reduced to 75 percent. More specifically, 49 percent of existing canebrakes were found within the 50-m stream buffer. Fourteen percent of the sites were found between 50 and 100 m, and 12 percent were found between 100 and 200 m.

As expected, potential giant cane landscapes >50 m from streams have a greater percentage of cropland than those near streams. Two-thirds of the potential giant cane landscapes within 50 m of a stream were grassland or forest. These land covers provide a much better opportunity for cane to be present than other land covers. However, lands within 50 m of streams do contain 25 percent cultivated crops. Lands between 50 and 100 m of streams have a similar ratio of land covers as those between 100 and 200 m: 46 percent cropland, 48 percent grassland or forest, and 6 percent developed.

DISCUSSION

More than half of the canebrakes were found within 50 m of a stream, and most of those were within 20 m and on a 1-percent slope or less. The total area of potential landscapes in the Cache River watershed is 14,590 ha, although this amount would be reduced to 7,470 ha by areas of existing forest, about 6,500 ha, and continuous open water, roughly 620 ha, neither of which is likely to be considered for cane restoration.

We think that identifying the potential giant cane landscapes demarcated by a 50-m buffer width would be an appropriate way to determine where giant cane could be used as a riparian buffer (Fig. 7). This conclusion is consistent with the statement by Griffith et al. (2009) that ideal cane restoration sites are on flood plains of rivers and streams where the rooting zone of the plant is out of the zone of saturation of the adjacent stream. It is also consistent with studies that present evidence that riparian buffers within 40 m of streams can reduce nitrogen, phosphorus, and sediment loads (Karr and Schlosser 1978; McColl 1978; Schlosser and Karr 1980, 1981a, 1981b). Although roughly one-half of the existing canebrakes are within the potential giant cane landscapes defined by a 50-m stream buffer and the soil parameters, the other half exist under a variety of conditions beyond stream proximity and the soil parameters analyzed. Therefore, more analysis is needed to determine the most appropriate areas for canebrake restoration.

The first round of groundtruthing showed the remote sensing process to be minimally accurate. Only two of the selected sample sites contained cane, and four sites were determined to be cypress trees. The second round of groundtruthing of the supervised classification process yielded very poor results. Only 2 of the 18 potential sites could be verified as existing giant cane.

It was difficult to delineate giant cane by using supervised image classification because of the similarity in reflectance signatures of giant cane and other species within the VNIR imagery. The spatial resolution (0.21-m pixels) was extremely good for image classification purposes, but the single near-infrared band of the imagery limited the ability to separate the cane and cypress signatures, as well as those of other evergreen species on the landscape. Imagery that provides a broader range of the electromagnetic spectrum could potentially solve this issue. Although satellite imagery currently available can provide this multispectral range, the small size of the typical giant canebrake may not be detectable by the larger spatial resolution of these platforms.

Light detection and ranging (LIDAR) could potentially be an alternative to traditional remote sensing platforms. A study of this type could be improved by LIDAR in two ways. First, LIDAR has the potential for species classification because the platform uses the same visible and infrared spectrum as some satellite sensors. To our knowledge, however, LIDAR has been applied to delineate only levels of vegetation, not species-specific classification. Second, LIDAR could be used in this study through its more common use, digital elevation models (DEMs). As shown, the best restoration areas for giant cane are within level flood-plain zones. A wetness index can determine where the greatest flow accumulation will occur based on elevation data, thus delineating areas of level flood plains. This approach was attempted for this study by using DEMs from the U.S. Geological Survey (USGS), but the USGS data are not detailed enough to create an adequate wetness index for our study area. The much greater spatial resolution of LIDAR offers potential to create a usable wetness index.

The 25 percent of the potential giant cane landscape (50-m buffer) that is cropland could benefit from a riparian buffer capable of reducing sediment and nutrient runoff from cropland. Ideally, at least some buffer width between crops and streams is recommended, though there are no regulations in Illinois requiring farmers to leave such a buffer. Canebrakes create thick networks of rhizomes belowground that effectively stabilize soils along riparian corridors. Giant cane would be very appropriate as a riparian buffer where buffer width is limited because its dense aboveground stands of culms result in litter accumulation and high soil porosity, which promote infiltration, inhibiting—and in some cases eliminating—the transport of sediment and nutrients into adjacent streams (Schoonover and Williard 2003; Schoonover et al. 2003, 2005). Therefore, a more detailed spatial analysis that would show the spatial relationship of crops, cane, and streams would be an important next step in this type of project.

CONCLUSIONS

Although this research showed some of the challenges in using GIS to determine current and potential sites of giant cane, it also provided some of the predominant topographic characteristics of canebrakes. The status of cane as a primarily riparian species was confirmed. We were able to determine appropriate soils for canebrakes located within 50 m of streams. The identification of potential sites could possibly be improved through further analysis. These analyses include potential runoff from agricultural fields. Current DEM information is not detailed enough for this landscape. A LIDAR data set could possibly allow for finer-scale evaluation. A more detailed analysis of the relationship between agricultural fields and the potential sites also could help to define sites in more immediate need of restoration. In the southern portion of the Central Hardwood region where the Cache River basin is located, riparian buffers may be critical for nutrient attenuation in upland riparian sites, where there may be less potential for denitrification relative to lowland areas with shallow water tables and greater tendency to flood (Blattel et al. 2009). Based on the current location of successful canebrakes, giant cane seems to be an excellent candidate for establishing riparian buffers.

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