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ARTICLE

Land use and land cover in a transitioning militarized landscape

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ABSTRACT

The repurposing of military lands is common in many parts of the world and presents a variety of conservation opportunities. This study examines land cover at Big Oaks National Wildlife Refuge, Indiana (U.S.A.) as it transitioned from military proving ground to wildlife refuge from 1985 to 2013. We use remote sensing, semi-structured interviews, and a review of planning and management documents to examine this transition. Limited change in land cover composition and distribution are detected, despite changes in use and management. This landscape similarity relates to similarities in land management practices, and the impact of landscape history on current management practices. The findings suggest that military use and conservation objectives at this site yield similar land covers and are not necessarily in contrast to each other. As military base closures continue, the potential to maintain and expand conservation opportunities on these lands will likely grow in importance.

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Introduction

Land use decisions commonly impact local environments, human well-being, and resource availability. Although many land use changes occur at local scales, the collective impact of changes made to local land use systems contributes to regional and global processes (Lambin, Geist, & Lepers, 2003). In the United States, the federal government owns approximately 28% of the country's 890 million hectare land base (Gorte et al. 2012). The US Department of Defense (DoD) controls and determines the use of nearly 7.7 million hectares of this land, a share that is roughly on par with that found in other countries (Woodward, 2004). Military lands are used for a variety of activities, ranging from training bases and communication installations to artillery ranges and proving grounds. The extent and location of the military land base changes during periods of war and peace, and are affected by training needs, new technologies, and conflict-specific interests of matching training environments with those found in conflict zones (i.e. high altitude, desert lands, tropical rain forest, etc.) (Demchak, 1991; Thorpe, 2014). Many of these factors also lead to modifications in the ways in which land controlled by the DoD is used.

Since the late 1980s, military lands in the United States have seen a series of systematic base closures and redesignations, the result of five rounds of a congressionally authorized Base Realignment and Closure (BRAC) commission. As one of many different outcomes for transitioning military lands, more than 400,000 ha of military land in the Unites States have subsequently been redesignated to new purposes of wildlife conservation (Havlick, 2007, 2011). Similar trends have occurred in other parts of the world as a result of post-Cold War reconfigurations, but these changes have been relatively little examined in terms of land use or land cover change (but c.f.

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Bicik & Vit, 1994; Kupkova, Bicik, & Najman, 2013; Prieler, Hamann, Anderberg, & Stigliani, 1996). The former Iron Curtain borderlands of Central Europe, for example, have been broadly recast as a series of protected lands, known today as the Green Belt of Europe (Coates, 2014; Havlick 2014). In sum, these transitions from military landscapes to conservation spaces represent significant changes in land use and land cover that deserve attention for their ecological and cultural significance. Many of the land use and land cover changes in post-military landscapes are also occurring in developed countries that are relatively underrepresented in the land change science literature, which has been more attentive to primary land cover conversions with an emphasis on deforestation dynamics in the tropics and subtropics (Jepson and Millington 2008). In recognition of this emphasis on deforestation dynamics in land cover change studies, research is being extended to address more varied land dynamics, for example, land cover change within agricultural and urban landscapes. Additionally, land use and land cover studies have examined the impacts of protected area designation on conservation, but most frequently via a comparison of land cover change within protected areas versus changes outside (e.g. Gibbes, Southworth, & Keys, 2009; Nagendra et al., 2013). Despite the increasing prevalence of land transfers from military possession and management to public use, and the potential conservation role that this land use transfer has in conserving tracts of contiguous habitat within a matrix of land uses increasingly dominated by built and agricultural land, this type of land transfer and associated land cover changes remain little studied.

In the United States, the process of redefining military land use is guided by the Federal Property and Administrative Services Act of 1949 and the Defense Base Closure and Realignment Act of 1990 (BRAC 2005). If the DoD determines land to be surplus, it can be transferred or disposed of in multiple forms, including leasing, allocation of the land for public benefit, and transfer of title. Shifts in land administration or land management objectives then alter use. These landscapes thus reflect, at least indirectly, changes in regional, national, or international priorities, military strategy, and politics.

Considering that the conservation contributions of military land management have been both critiqued and lauded in popular and scholarly publications (e.g. Leslie, Meffe, Hardesty, & Adams., 1996; Sanders, 2009; Ward, 2015; Woodward, 2004), the transition of military lands to new purposes of wildlife conservation warrants further analysis in terms of land use and land cover changes. The continued streamlining (and in some locations, expansion) associated with changes in military structure and strategy suggests that this form of land conversion will become increasingly significant as they relate to conservation lands. The conversion from military use to wildlife refuge is not always a dramatic form of land conversion, as many military lands receive little treatment upon closure or redesignation. Transitions from military to conservation lands hold the potential to yield subtle changes in land cover that reflect changes in the land use designation. These sometimes subtle modifications to land use are increasingly recognized as important from the perspective of conservation and provisioning of suitable habitat (Verburg et al., 2015). The designation of some former military lands as protected areas within the National Wildlife Refuge (NWR) System managed by the US Fish and Wildlife Service (FWS) carries with it a new expectation for the land to be administered in a manner that conserves wildlife and plant resources for public benefit. The conservation mission assigned to these lands alters human interactions with the environment in this space and contributes to the constant redefining of the landscape.[1]

In this study, we examine post-military land changes within the Big Oaks National Wildlife Refuge (BONWR), Indiana (U.S.A.). We ask: what land cover changes and, by extension, conservation priorities are evident from this military transition to wildlife refuge? We measure land cover change, from 1985 to 2013, using remote sensing analysis and rely on analysis of semi-structured interviews with wildlife refuge officials, and BONWR conservation and land use management plans to develop an understanding of the effect of land use changes on land cover, and the decisions shaping land use. In this way, we examine how land cover has changed as a result of military repurposing and the transition to management as a new wildlife refuge.

Methods

Study area

BONWR encompasses approximately 20,500 ha across Jefferson, Jennings, and Ripley counties in Southeastern Indiana, U.S.A. (Figure 1). During the past century, this site has witnessed distinct phases that prioritized agricultural, military, and conservation use, creating changing land management objectives that produced farmland from forest, a bombing range from farms, and, most recently, a wildlife refuge from a bombing range (Havlick, 2011). Each of these changes has been accompanied by social and ecological consequences, including how policy makers and the public view land dedicated to conservation activities or military use. Prior to establishment of the wildlife refuge, the land was managed as the Jefferson Proving Ground (JPG), a US Army munitions testing facility. At times, up to 85% of all US Army munitions testing was conducted at JPG (Disposal and Reuse of the Jefferson Proving Ground, Madison, Indiana, 1995; Shulman, 1992). After operating for more than five decades, BRAC commission-directed military reductions and consolidation led to the closure of JPG in 1994.

In 1996, the Army and FWS entered into a 3-year Memorandum of Agreement (MOA) for the FWS to begin natural resource management of this militarized landscape and to explore its potential as a NWR. The disposal and reuse processes for transferring management to the FWS included a screening to determine demand from potential users and an environmental impact assessment (Disposal and Reuse of the Jefferson Proving Ground, Madison, Indiana, 1995). In 2000, the Army, FWS, and Air Force entered into a MOA that provided the parameters for the establishment of BONWR through a 25-year real estate permit. Under this arrangement, the FWS is

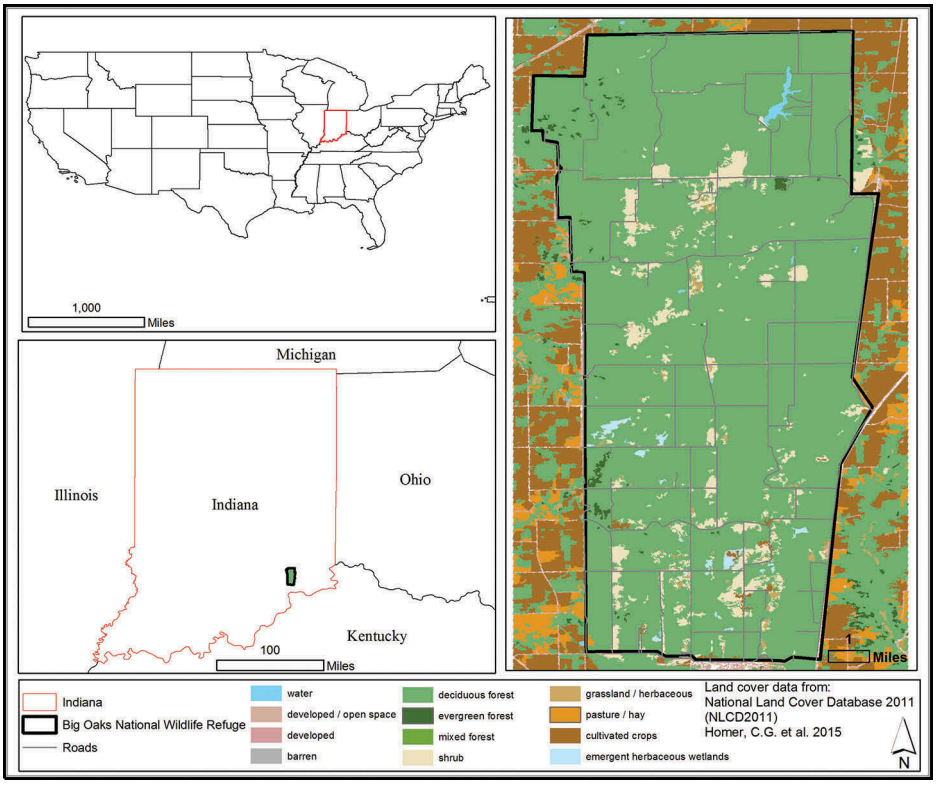

Figure 1. Big Oaks National Wildlife Refuge (BONWR) boundary and land cover as measured in the most recent National Land Cover Database (NLCD 2011) (Homer et al., 2015).

responsible for daily management on the refuge portion of the property, but liability for the past munition testing remains with the Army. The BONWR mission is to 'preserve, conserve, and restore biodiversity and biological integrity for the benefit of present and future generations of Americans' (US FWS 2006). The refuge is designated as a globally important bird area, and provides suitable habitat for rare species such as Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), crawfish frog (*Lithobates areolatus*), cerulean warblers (*Steophaga cerulea*), Henslow's sparrow (*Ammodramus henslowii*), and many other migrant birds. Approximately 2,000 ha of the refuge are open for limited public use, but the primary objective for refuge managers is maintaining and protecting wildlife habitat; land use and management strategies are subsequently directed toward this (U.S. Fish and Wildlife Service, 2006). The main land management strategies used to address this objective are strict limits on public use and access, and the implementation of a prescribed fire regime.

Fire is identified by a Wildland Fire Management Plan (FMP) for BONWR as a critical ecological process for habitat management (U.S. Fish and Wildlife Service, 2006). The fire regime, and land cover, in BONWR has been shaped by prior land uses which include periodic disking, herbicide use, mowing, and fires ignited by the Army, which intentionally maintained cleared areas for munitions testing and also caused unplanned burns as munitions exploded. The frequent presence of fire maintained areas of early successional habitats. To fulfill its mission as a NWR, BONWR managers continue to use fire, determined annually prescribed fires, for habitat maintenance (see Figure 2). The implementation of the FMP thus provides an example of the legacy of past (military) management practices and the connection between past and present land uses.

Land cover change

At BONWR, we conducted land cover change analysis for a time period spanning 28 years and crossing three land administration regimes – possession and management by the US Army, interim natural resource management by the FWS, and management as BONWR by the FWS. A land cover was characterized and measured over time using a land cover classification and a vegetation index. We used cloud-free Landsat data, selected based on availability, seasonal comparability of image scenes, and with the objective of having at minimum a decadal observation before and after the transfer in land administration at BONWR. Image dates used for change analysis and an associated land management time line are shown in Table 1. Radiometric calibration was conducted on all imagery in order to correct for atmospheric differences across dates, and account for systematic platform shift (Green, Schweik, & Randolph, 2005). Imagery was also georectified using the 2013

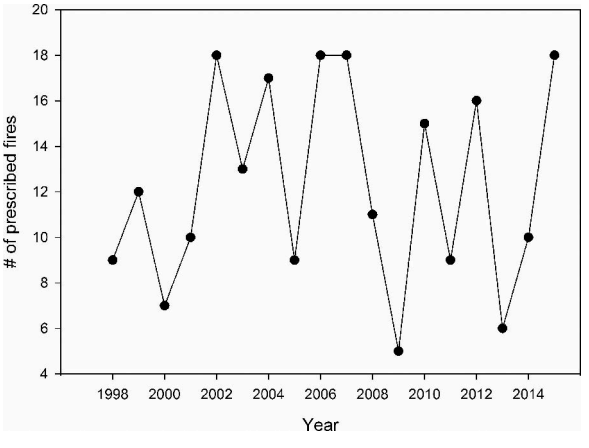

Figure 2. Total number of prescribed fire as recorded by the US Fish and Wildlife Service.

Table 1. Imagery used for land cover change analysis and land management associated with the image dates.

Image date	Image source	Land management
June 1985	Landsat TM	Management and possession by the US Army
June 1990	Landsat TM	
July 1997	Landsat TM	Natural resource management responsibility by USFWS by agreement with the US Army, ownership remains with the Army
July 2000	Landsat TM	USFWS established Big Oaks National Wildlife Refuge, Army issued real estate permit but retains ownership
June 2010	Landsat TM	
June 2013	Landsat TM	

image as the base image for the rectification process (Cassidy, Southworth, Gibbes, & Binford, 2013; Gibbes et al., 2009; Sheffield & Morse-McNabb, 2013) Gaussian maximum likelihood classifications, using a combination of *in situ* observations with Google Earth reference (see Clark & Aide, 2011 for further discussion), were applied to all imagery in order to categorize the landscape using the following classification taxonomy: forest, open savanna, grassland, shrubland, water, and transitional. The 'transitional' class contains areas in the landscape that are sparsely vegetated, recovering from recent burning, or contains a mixture of built surfaces and vegetation.

The determination of the classification taxonomy was guided by the BONWR mission to conserve one of the largest contiguous blocks of forest and grassland mosaics in Southeast Indiana (U.S. Fish and Wildlife Service, 2006). Due to the limited availability of verification data, *in situ* or otherwise, for earlier years of imagery, classification accuracy was measured for the 2013 image. Using random sample, 124 sample points were randomly selected and used to test the classification accuracy using a combination of in situ land cover knowledge and visual interpretation of high-resolution imagery available through Google Earth (Clark & Aide, 2011). We applied the spectral signatures for each class generated through the classification procedure for the 2013 image to earlier image dates (Cassidy et al., 2013). Land cover change across the three land administration regimes was measured using an additive change trajectory approach.

It is valuable to use index-based analysis, such as the normalized difference vegetation index (NDVI) (Southworth, Munroe, & Nagendra, 2004; Zeller, McGarigal, & Whiteley, 2012), in addition to classifications, as this coupled approach addresses the limitation of the discrete nature of classifications. The combined use of discrete classification and index-based analyses supports the identification of information about variation in land cover, which in some instances may relate to within-class dynamics (Southworth & Gibbes, 2010). We used NDVI to explore changes in land cover that may not be captured using a land cover classification. Although multiple vegetation indices exist, NDVI is extensively used for measuring changes in vegetation (Higginbottom & Symeonakis, 2014), evaluating conservation implications (Berry, Mackey, & Brown, 2007), the relationship between NDVI and vegetation productivity is well established, and the index has been effectively used to measure environmental responses (Pettorelli et al., 2005). Changes in NDVI were assessed using a mean–variance plot. Mean–variance plots are a form of graphical analysis that describe the pattern or change in the state of a system through time and are useful for measuring intra-class land cover changes not detected by a classification approach but indicative of ecosystems changes (Morse, Perry, & Smith, 2000; Pickup & Foran, 1987; Washington-Allen, Ramsey, West, & Norton, 2008). The combined use of NDVI mean and variance captures not only the overall greenness but also the measure of the range in greenness across landscape. In a mean–variance vegetation index plot, the plot indicates interannual changes in vegetation, where the mean values for NDVI are correlated to vegetation cover or density and the variance values are related to the vegetation heterogeneity (Sellers 1985, Gibbes, Southworth, Waylen, & Child, 2014; Pickup & Foran, 1987; Washington-Allen, West, & Ramsey, 2003).

Stakeholder interviews and document analysis

As a means of augmenting information provided from remote sensing between 2004 and 2013, we conducted more than a dozen semi-structured interviews with key stakeholders involved in the transition and management of the BONWR site. Interviewees included the BONWR refuge manager, officials responsible for managing prescribed fire on the site, FWS wildlife and contaminant biologists, civilian and Army officials responsible for transitioning the JPG out of Army control, and leaders of nongovernmental organizations focused on environmental protection and/or historic preservation at the BONWR site. The interview questions focused on individuals' perspectives on restoration goals at the BONWR site, and how they evaluated the relative importance of ecological restoration, historical preservation, and public use. Interviews were recorded and transcribed, and lasted 30–90 minutes in duration. Interviews were also supplemented by extensive document analysis, from materials accessed between 2004 and 2016 at the US FWS files at BONWR, the facility's designated archives maintained at nearby Hanover College (Hanover, Indiana), and from agency documents posted online.

Results

Land cover change

The results of the land cover classification provided quantitative measures of land cover and spatial representations of the distribution of forest, open savanna, grassland, shrubland, water, and the transitional land cover class at each time step (1985–1990–1997–2000–2010–2013). The accuracy assessment yielded a kappa value of 0.81. The error matrix and corresponding measures of accuracy suggested that the greatest classification challenge lies with the discrimination of the grassland and transitional classes (Table 2). Figure 3 shows land cover in the refuge at each point of observation across the 28-year study period and Figure 4 presents the total % of the landscape per class at each observation and the net change in land cover over time. The classification for each date indicated that shrubland was consistently the class with the highest coverage within the refuge, typically covering about 45–47% of the refuge. Shrubland was relatively stable as a land cover type across the study time period, with a slight decline occurring from 1985 to 1990 and an increase occurring from 2010 to 2013. Shrubland was particularly evident across the study time period in the central section of BOWNR (Figure 3). Hardwood forest and savanna were the next two most prevalent land covers in BONWR; these land covers combine accounted for between 22% and 37% of the refuge, and across all years was more relatively well distributed throughout the study area (Figure 3). The lowest occurrence of hardwood forest and savanna occurred in 1985 when the area was an active artillery range controlled by the US Army. Hardwood forest and savanna have generally increased in extent over the study time period, with small exceptions (1% decrease) from 1997 to 2000, and 2010–2013.

The land cover with the greatest variation in coverage across the study time period was grassland, this detected pattern is influenced by the observed decreases in grassland since 2000, though this can also be a manifestation of the error rate (Table 2). The water and transitional classes were the most stable land covers across the study time period, although the spatial location of the transitional class varies. The spatial distribution of the land cover classes, as depicted in Figure 3, showed a high and increasing clustering of hardwood forest in the northern portion of the refuge, though some increase in hardwood forest in the central region

Table 2. Error matrix for the accuracy assessment of the 2013 image.

	Forest	Open savanna	Grassland	Shrubland	Water	Transitional
Producer's accuracy	86.2	87.5	53.6	69.2	85.7	58.1
User's accuracy	83.3	53.8	68.2	64.3	85.7	72.0

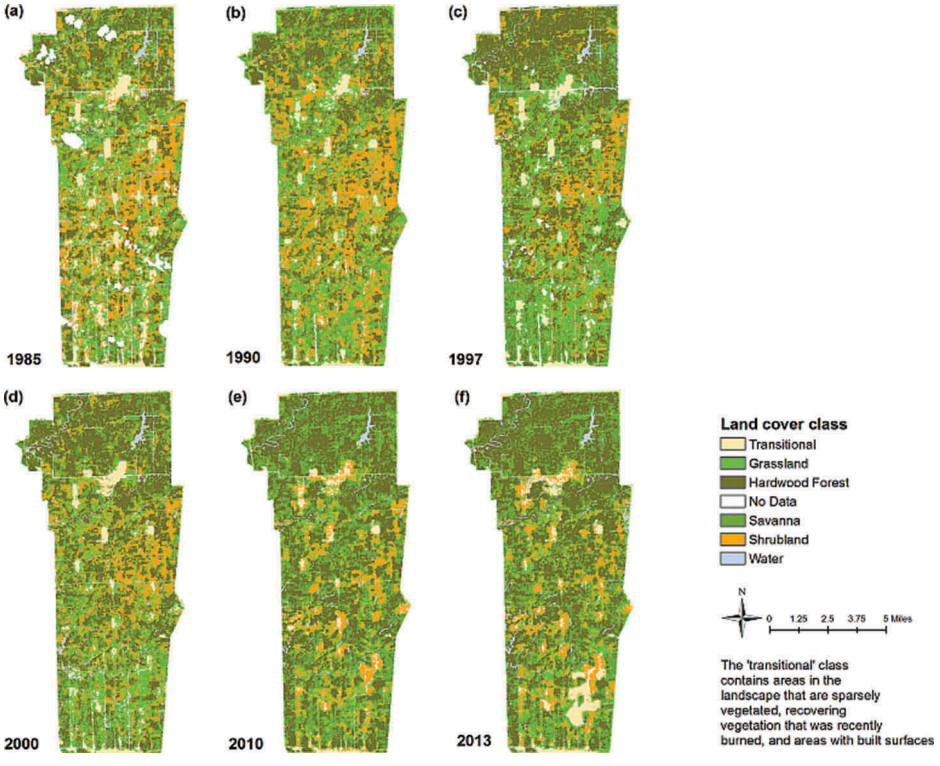

Figure 3. Distribution of land covers at each observation time point (a) 1985, (b) 1990, (c) 1997, (d) 2000, (e) 2010, and (f) 2013.

of the reserve was also observed. The spatial clustering of hardwood forest was particularly evident from 1997 onward, after natural resource management by the FWS. The results of the classification also indicated that open savanna, shrubland, and grassland were intermixed and dispersed throughout the central and southern portions of the refuge (Figure 3). The transitional land cover class, which represents areas that are sparsely vegetated, recovering vegetation that was recently burned, or mixtures of built surfaces and vegetation, was located primarily in the north central part on the Indiana Air National Guard Jefferson Range, along roads, and within prescribed burn areas.

The results from an additive change trajectory identified the highly spatially dispersed nature of land cover change within the refuge. During the first time change period, a period of Army use from 1985 to 1990, land cover change results indicated the largest increases occurred in shrubland and savanna, 28% and 27% of all change, respectively, (Figure 4). There was a lack of dominance of a single trajectory of change, defined here as a large reduction in any one class corresponding to an increase in another class. From 1990 to 1997, and 1997–2000, a greater increase in forest was observed than during the initial time step, with up to 27% of all change being characterized by increases in forest. Simultaneously, the savanna and grassland covers experienced similar quantities of change as those seen in the change measured from 1985 to 1990. The increases in forest were most commonly associated with shifts away from shrubland and a closing of the canopy which is observed by the 1997 image date. The land cover change analysis which compares the 1985 landscape to the most recent observation of the landscape, in 2013, showed the largest increases in forest and savanna, and overall decreases in the presence of shrubland.

Figure 5 shows a mean NDVI value for the entire refuge plotted against NDVI variance for each observation (date) in the dataset. The results show that there has been relatively small change in the mean NDVI values across the study time period. Mean NDVI values ranged from 0.58 to 0.70,

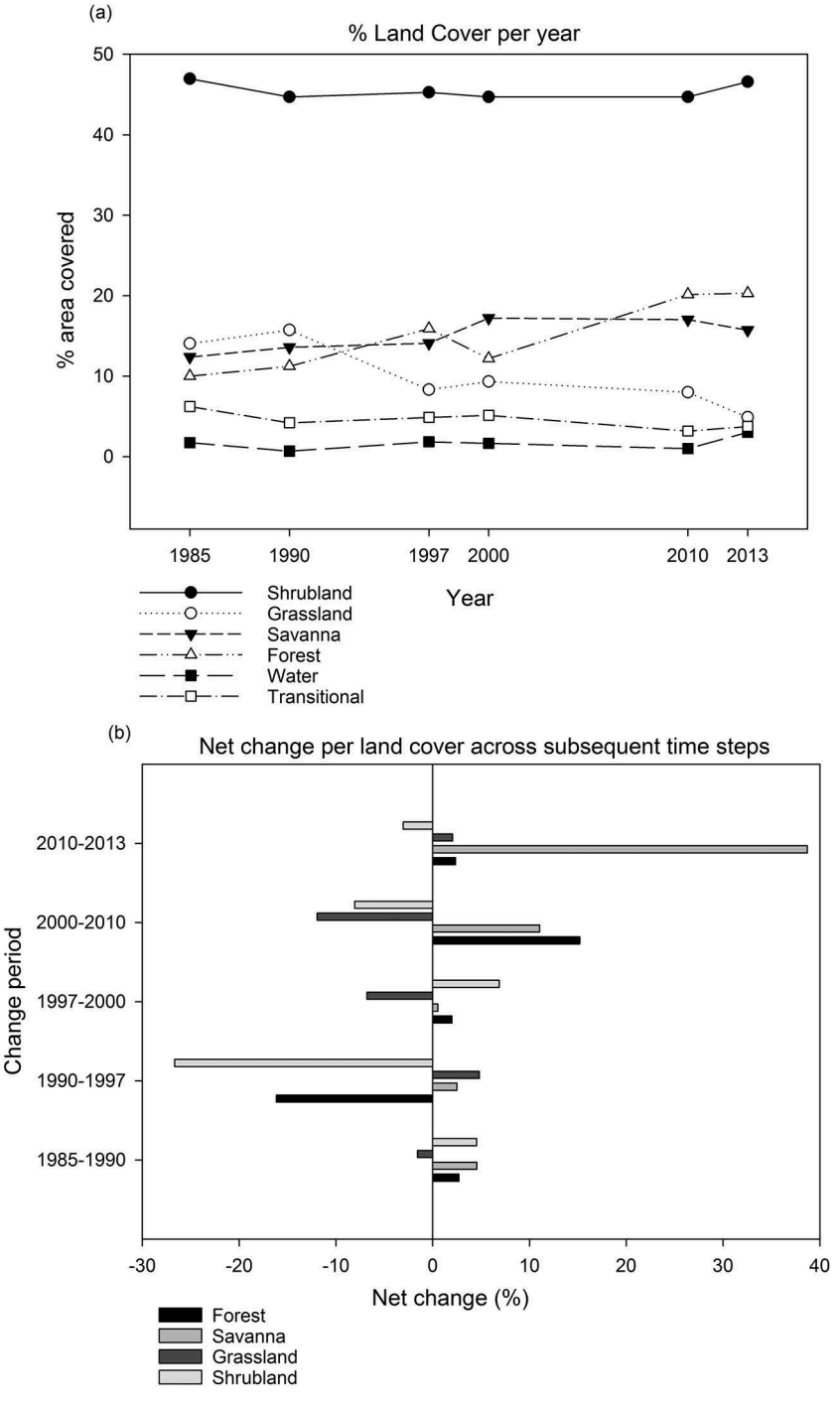

Figure 4. (a) BONWR land cover classification results for 1985–2013 (b) Net change in land cover across observation periods.

and the pattern of change indicated a return to similar mean NDVI values from 1985 (0.66) to 2013 (0.64). The highest NDVI variance was seen in 1985, and there has been a decrease in variance since this time point, with variance values decreasing from 0.011 in 1985 to as low as 0.005 in 2010, and then returning to 0.007 in 2013. Higher NDVI values tended to be situated in the northern portion

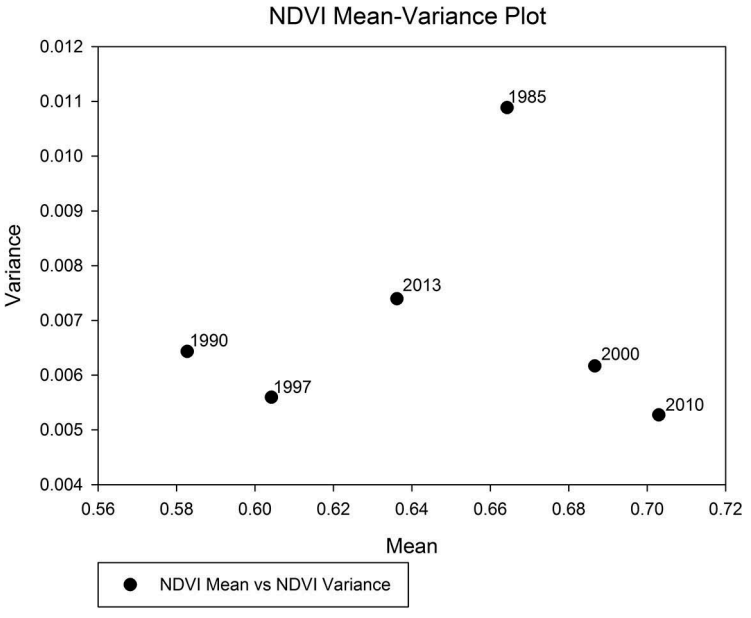

Figure 5. Mean–variance plot of NDVI values.

of the refuge, in areas corresponding to hardwood forest. Consistently low NDVI values are associated with the live fire range operated by the Indiana Air National Guard.

Stakeholder interviews and document analysis

Interviews with key Army and FWS officials involved in the operations of the JPG/BONWR site during the three phases examined in our study period reveal aspects of both continuity and change as the facility transitioned from military to conservation priorities. According to these accounts, the most dramatic transition in land cover and ecological character occurred following the Army appropriation of the site – a time period that predates our analysis and the availability of remotely sensed images – rather than the transition from military to FWS control. Army and FWS officials, alike, described the decades from the early 1950s through the 1980s as a period of rapid afforestation, and noted the steady succession of relatively homogenously cleared agricultural lands into a patchwork of forests, savanna, shrublands, and grasslands; in other words, into an approximation of the land cover mosaic that exists today.

Two species that are now common across BONWR, wild turkey (*Meleagris gallopavo*) and white-tailed deer (*Odecoileus virginianus*), either naturally recolonized or were introduced to JPG during the decades of Army management. Beaver (*Castor canadensis*), too, were scarce or nonexistent prior to Army control, but now thrive at BONWR. Both Army and FWS officials credit the habitat changes that occurred during this period as essential to the later return of river otter (*Lontra canadensis*), bobcat (*Lynx rufus*), numerous songbirds, and other locally or regionally rare species.

Interviews highlighted one obvious companion effect of the Army's creation of the JPG and the eviction of the land's residents and human communities was a reduction in public access. Although public use remains limited to specific areas and specific days and hours under FWS management, the new objectives for the site as a wildlife refuge have led to a number of changes, some of which affect land cover. In our interviews, FWS officials indicated that broad changes to land cover and habitat configurations were not realistic – flipping the location of grasslands and forests, for example – but that they actively worked with prescribed fire, in particular, to maintain grassland

and shrub habitats. FWS managers also have mostly granted beaver considerable leeway to build dams and modify stream habitats, whereas Army managers trapped and more severely limited the expansion of these large rodents.

Our interviews also highlighted that following the cessation of Army operations at the site, FWS biologists were able to conduct biological inventories to better understand baseline conditions starting in the mid-1990s. Army and FWS documents further describe funding details and include reports that eventually set the stage for the creation of an overlay refuge at BONWR (see Blanchard, 1994; Hedge, Homoya, Hedge, & Baker, 1993; Longhouser & Hartwig, 1997; Pruitt, Pruitt, & Litwin, 1994). As turkey (*M. gallopavo*) and white-tailed deer (*O. virginianus*) populations surged, public use and appreciation of the habitat amenities of the JPG also grew thanks to popular fall hunting seasons.

Discussion

Through the use of remote sensing analysis, we measured land cover across a 28-year time period. The measured changes in land cover correspond to land management shifts from the US Army to the US FWS for use as a NWR. The land cover changes in BONWR were not characterized by large swaths of land within the refuge changing from one cover to another, but rather by the small changes between classes that are the focus of conservation strategies employed – hardwood forest, shrubland, and grassland. The lack of dominance of a single trajectory of change, defined here as a large reduction in any one class corresponding to an increase in another class, could be associated with decreased active use by the Army resulting in the less controlled/managed vegetation growth and more varied change trajectories. The change trajectory periods of 1990–1997 and 1997–2000, encompassed the transition period during which the refuge shifted from FWS management to an overlay refuge where land title still belonged to the Army but resources were managed by the FWS. During the period after the management transition from Army to FWS, active management of the landscape for conservation purposes occurred and included the implementation of plans such as the BONWR fire management plan. The land cover analysis indicates that this period was dominated by shifting mosaics of grassland and savanna. These changes aligned with the refuge goal of maintaining shrub and woodland mosaics intermixed with grasslands.

Changes in the NDVI values were indicative of changes in vegetation throughout the entire reserve, regardless of land cover. The changes in mean NDVI values and variance values are small in comparison to other studies of land cover change which have used this form of analysis (see for example, Cui et al. 2013) and suggest that the total vegetation cover in the refuge has had limited change over time, and landscape heterogeneity initially decreased but has most recently experienced an increase. Although land cover, measured through classification or index approaches, is not the only measurable expression of land use change, it is one that can be related to ecological changes and shifts in management practices associated with new land use designations.

The majority of the Big Oaks site is now dedicated to goals of wildlife conservation, land cover is explicitly treated using prescribed fire, mowing, and other measures to maintain grasslands and forest openings. The FWS faces a challenging task of trying to prioritize ecological function and habitat conservation at the site, while also contending with widely scattered remains of the military testing that occurred here for more than five decades. Unexploded ordnance (UXO) is ubiquitous over much of the refuge, a depleted uranium firing range remains largely in place near the south-central portion of the refuge, and the north-central portion of the site continues to accommodate Jefferson Range, a 500-hectare live fire range operated by the Indiana Air National Guard. Each of these elements creates constraints on what kinds of management operations wildlife officials can conduct while also maintaining public safety and limited public recreation opportunities. As the agency notes in its Wildland FMP for BONWR, 'In all suppression activities, the presence of UXO and depleted uranium (DU) contamination must be considered' (2006, p. 11).

In 2013, BONWR initiated the process to develop a Comprehensive Conservation Plan that will formalize management objectives for a 15-year period. The challenge of maintaining an appropriately diverse mix of habitat features is already among the issues highlighted by refuge managers. Key concerns include how to maintain or connect the current area of existing grasslands, reconnect forest fragments, restore disturbance regimes, and maintain shrubland–woodland complexes. The species currently utilizing BONWR vary widely in their habitat requirements, and some activities such as prescribed burning may benefit grassland-dependent species, such as Henslow's sparrows (*A. henslowii*) and crawfish frogs *(L areolatus*), but need to be conducted in ways that minimize risk to others such as the threatened northern long-eared bat (*M. septentrionalis*). To guide the management of fire at BONWR, FWS planners have divided the refuge into four Fire Management Units, ranging in size from 4450 to 6000 ha (U.S. Fish and Wildlife Service, 2006).

The total amounts of land cover at each time step of the remote sensing analysis may suggest that land cover treatments overall have not kept up with processes of forest succession and encroachment, as forest cover has increased since 1985, particularly in the northern section of the study site (Figure 3). However, the changes in other key habitat-related land covers such as grasslands and shrublands submit otherwise. The measures of percent land cover when considered in concert with the net changes (Figure 4), the spatial distribution (Figure 3), and limited change in NDVI, highlight limited overall change. The conservation concerns for BONWR management which include to maintenance of grasslands and shrubland–woodland matrices, however, no exact quantity of each land cover is identified in management plans, thus the restricted changes could be interpreted as success with regards to land cover maintenance.

A lack of vast and sudden shifts in land cover across the three managements could suggest that these managements are potentially more similar than might expected. Baumann and Kuemmerle (2016) discuss that the effects of warfare on land systems are varied and multidirectional. Potentially the limited land cover change in BONWR indicates that the impact of this war-related land use is not necessarily contrary to conservation land management objectives. However, the interviews analysis in particular highlights that prior managements have shaped latter conservation strategies yielding analogous landscapes. Given the constraints of operating in what remains effectively a militarized landscape contaminated by UXO, FWS personnel have to operate in what one manager described as an, 'opportunistic-pragmatic' approach. The prescribed burn program at BONWR aims to manage approximately 4000 ha annually, but is required to avoid ground-disturbing activities such as constructing fire lines, and due to UXO issues, authorization by the Army for certain management practices is necessary (U.S. Fish and Wildlife Service, 2006, p. 41).

In our semi-structured interviews, refuge personnel pointed to a variety of constraints that affect how they can manage their lands for conservation values. As one manager explained, 'We're certainly interested in endemics and rare plant and animal species that are located on the property, and how we can restore and manage these natural heritage values. But because of the history of agricultural soil depletion and changes inherent with that and the influence of a surrounding agricultural landscape and the introductions of invasive exotics, we have limitations. We have to realize the past history influences our choices.' The lasting impact of military land use, through the continued shaping of conservation strategies, is comparable to findings in the existing literature that warfare, and in this instance land uses related to warfare, have long-lasting land use legacies (Baumann & Kuemmerle, 2016).

At Big Oaks, FWS personnel use fire and other ecological restoration treatments to influence the condition and pattern of refuge habitats. These practices, particularly the use of fire, are likely the major shaping factor for the observed fluctuations in land cover. It is also evident that the active management is shaped by the prior military and agricultural uses of the site, and result in relatively unchanging land cover distribution. As the refuge manager described his approach, 'We're here as a refuge because of the natural biodiversity that was here, so our management will center on these rare species and influence how we maintain their habitats to keep populations at healthy levels.

Our current Comprehensive Conservation Plan process will evaluate the refuge to see if it is valid to manage the site as a complex of large forest, large grasslands, savanna and shrubland.'[2]

FWS has either not needed to or not been able to dramatically change land cover characteristics since it took over active management in the late 1990s. One understanding is that the Army's impacts created a broad mixture of land cover that has translated relatively well to conservation purposes. The results suggest that the active use of the land during both Army use and refuge management yielded similar land covers within the BONWR; although there is some shift in the distribution of land cover, there are continuously present patches of all land covers, and the refuge as a whole has similar proportions of each land cover type across the different managerial regimes. As we indicated in the Results section, above, almost certainly the most dramatic land cover changes occurred prior to our study period during the transition of this site from privately held agricultural lands to federally controlled Army proving ground. The continuity of land cover at BONWR provides evidence for its sustained success in maintaining forest, grasslands, and shrublands, within a predominantly agricultural landscape.

Conclusions

We use measured land cover across varied land use and management periods to examine whether changes in land use and management have yielded different land cover compositions, which in the case of BONWR is an indicator of conservation success. At BONWR, one conservation goal is to maintain grasslands and shrub–woodland complexes as they support a suitable habitat for wildlife, in particular for rare species. These land covers are in many cases legacies of prior military use and, before that, agricultural clearing of native forest. Current land use strategies primarily rely on limiting most public (or extractive) uses and prescribing fire to maintain the presence of grasslands and shrub–woodland complexes within the refuge for conservation purposes. Considering the early agricultural use of the area, military impacts spanning five decades, and the more recent conservation-oriented directives of the refuge, the limited changes we measured in land cover make it difficult to assess or disaggregate which uses have most contributed to creating a successful conservation landscape. The limited measurable land cover change across management regimes suggests with regard to using land cover as an indicator of conservation success there is little difference between military land use and recent conservation use. At this scale of analysis, neither land use – military or wildlife refuge – appears to convey a distinct advantage in maintaining conservation-relevant land cover. Although small changes in land cover occurred, they are not spatially clustered, there is no dominant change trajectory, and the overall composition of the landscape is relatively stable. What is clear, however, is that this sequence of land uses has created conditions that make BONWR stand out amid the agricultural land use matrix surrounding the refuge. The military's period of institutional control and exclusion has been followed successfully by conservation-focused management to maintain a relatively controlled setting heterogeneous enough to support a regionally distinctive ecological community. As military base closures and land use changes continue, in the United States and elsewhere, the potential to maintain and expand conservation opportunities on these lands will surely only grow in importance.

The limited nature of land cover change in BONWR might make it tempting to overlook the significance of this or other military-to-conservation land use conversions. Unlike vast tracts of forest loss, small shifts in land cover and vegetation do not present a narrative of dire circumstances. However, subtle land cover changes that occur across multiple sites can also prove to be important and are increasingly recognized as key to contemporary conservation efforts (Verburg et al., 2015). Limited land cover change may be indicative of maintenance of landscape dynamics and habitat provisioning, such as shifts between grassland and shrubland in response to the use of prescribed fires. The absence of sharp and sudden changes, might be linked to continued ecosystem resilience (Zurlini, Zaccarelli, & Petrosillo, 2006, Gunderson and Holling 2002). Counter to traditional notions of ecological restoration, which focus on returning a landscape to

presettlement conditions, our analysis suggests that in the case of BONWR, conservation may be succeeding by maintaining the site in a *post-military* condition. Here and in similar sites being recast from military to conservation goals, the transitions out of military use may not require or even benefit from a return of the land cover to the conditions of pre-military use. In fact, military land use practices and refuge conservation strategies may be more aligned than are often recognized. BONWR continues to rely on policies of restricted access, limited public use, and fire as conservation strategies, offering an example of how refuge officials are maintaining practices that also existed – though clearly for different purposes – during the period of Army use. The more critical, and perhaps intuitive, assumption of military land uses *necessarily* being opposed to conservation purposes, at least in this case, appears not to pertain. Given the extensive modifications to the Earth's surface, finding and building conservation opportunities from an array of prior land uses, including the often dramatic impacts wrought by military training and testing, could prove to be an important addition to how conservation is practiced and pursued in decades to come. The case of BONWR illustrates some of the limitations to this approach, and also its very real potential.

Notes

1. These military-to-wildlife transitions are not limited to terrestrial environments. Marine protected areas created by Presidents George W. Bush and Barack Obama have added more than 120 million hectares of Pacific Islands, atolls, and marine ecosystems as National Monuments and Wildlife Refuges. Many of these sites were formerly managed as military airfields and/or weapons testing sites.
2. Due to his contributions of in situ knowledge, refuge planning processes, and management objectives, the refuge manager was ultimately added as an author to this paper.

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