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Key Areas For Conserving United States' Biodiversity Likely Threatened By Future Land Use Change

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Key areas for conserving United States' biodiversity likely threatened by future land use change

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Abstract. A major challenge for biodiversity conservation is to mitigate the effects of future environmental change, such as land use, in important areas for biodiversity conservation. In the United States, recent conservation efforts by The Nature Conservancy and partners have identified and mapped the nation's Areas of Biodiversity Significance (ABS), representing the best remaining habitats for the full diversity of native species and ecosystems, and thus the most important and suitable areas for the conservation of native biodiversity. Our goal was to understand the potential consequences of future land use changes on the nation's ABS, and identify regions where ABS are likely to be threatened due to future land use expansion. For this, we used an econometric-based model to forecast land use changes between 2001 and 2051 across the conterminous U.S. under alternative scenarios of future land use change. Our model predicted a total of ~100,000 to 160,000 km² of natural habitats within ABS replaced by urban, crop and pasture expansion depending on the scenario (5% to 8% habitat loss across the conterminous U.S.), with some regions experiencing up to 30% habitat loss. The majority of the most threatened ABS were located in the Eastern half of the country. Results for our different scenarios were generally fairly consistent, but some regions exhibited notable difference from the baseline under specific policies and changes in commodity prices. Overall, our study suggests that key areas for conserving United States' biodiversity are likely threatened by future land use change, and efforts trying to preserve the ecological and conservation values of ABS will need to address the potential intensification of human land uses.

Key words: biodiversity conservation; habitat loss; land use/land cover change.

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INTRODUCTION

Land use change is one of the main causes of biodiversity loss and therefore critical for conservation planning (Chapin et al. 2000, Fleishman et al. 2011). Expanding land use for agriculture, pasture, and urban development, replaces and degrades natural habitats, reducing native biodi-

versity and altering many ecological processes (see Foley et al. 2005). About two thirds of the terrestrial biosphere has already been converted or altered by such land uses, and even more will likely be altered in the future to satisfy the needs of an increasing human population (Ellis et al. 2010). Evaluating future land use changes and their potential impacts on important areas for

biodiversity is therefore an important task, because it can help to identify probable threats to biodiversity as well as conservation opportunities, providing valuable information for land use planning, conservation strategies, and policy making (Pressey et al. 2007, Moilanen et al. 2009, Radeloff et al. 2010). Furthermore, understanding land use change is critical to mitigate the potential negative effects of climate change (Groves et al. 2012). However, the location of future land use change matters, since some areas are more important for biodiversity conservation than others.

Identifying the location of important areas for biodiversity is a critical step in conservation efforts, as they represent priority areas to sustain habitats and ecological processes (Moilanen et al. 2009). Recently, The Nature Conservancy (TNC) and partners have identified and mapped the nation's "Areas of Biodiversity Significance" (hereafter ABS), constituting those most important and suitable areas for the conservation of native biodiversity (Groves et al. 2002, 2003). ABS represent the best remaining examples of the full diversity of native species, natural communities and ecosystems for each ecoregion, and in number and distribution patterns across environmental gradients sufficient to sustain them for the long term (Groves et al. 2002, 2003). Thus, properly managing ABS and their ecological processes should help conserve most, if not all, native species and communities of the U.S., not just those that are rare, threatened or endangered. The question is though how much pressure from intensifying land use these ABS are likely to experience in the future. Quantifying future land use change on ABS could help identify potential threatened areas, pinpoint regional priorities for actions, and guide strategies to enhance biodiversity conservation (e.g., Doremus 2003, Bengston et al. 2004, Pressey et al. 2007, Wilson et al. 2007, Fishburn et al. 2009a, b).

The question how much land use will change in ABS is pertinent, because in general, econometric models project land use in the United States to intensify substantially, largely to the detriment of natural habitats (Radeloff et al. 2012), but there are pronounced regional differences. For example, the extent of natural grasslands/shrublands is expected to decrease by 0.2 million km², by 2051, with some regions in the

West experiencing declines of up to 25%. Forests, on the other hand, are projected to increase overall by 7%, yet major forested ecoregions such as the Appalachians, the Upper Northwest, and the Pacific Coast could be projected to lose forests.

In addition to regional differences, there are also differences depending on future policy scenarios, making some regions more or less prone to change (Radeloff et al. 2012). Land use differences among policy scenarios have been also forecast by empirical models, for example, to project land use changes in the Great Plains by 2100 (FORE-SCE; Sohl et al. 2012). Profit-maximizing scenarios projected significant loss of natural land covers and expansion of agricultural and urban land uses, while environmentally-oriented scenarios projected only modest declines of natural land covers at most (Sohl et al. 2012). Scenarios of future land use have been used to evaluate potential habitat changes around protected areas (Gude et al. 2007), to understand the social implications of future land use change (Pocewicz et al. 2007), and to support climate change assessments (Rounsevell et al. 2006), among others. The use of scenarios, rather than just one projected future state, thus can expand our knowledge about potential states and outcomes under alternative decisions, making them valuable for assessing the potential consequences of future environmental change (Polasky et al. 2011).

Our goal was to understand the potential consequences of future land use changes on the nation's ABS, and identify regions where ABS are likely to be threatened due to future land use expansion. In this study, we used future habitat loss within ABS as the main indicator of potential threat. Specifically, our objectives were to:

1. quantify current land cover and land use in the nation's ABS;
2. quantify future habitat loss in ABS using an econometric land use model, for a business-as-usual and different policy scenarios between 2001 and 2051;
3. evaluate regional differences in habitat loss across the nation's ABS;
4. identify regions where ABS are likely to be threatened by future land use changes.

METHODS

Our main approach consisted in using the land use model from (Radeloff et al. 2012) to quantify future habitat loss in the Areas of Biodiversity Significance of the conterminous U.S. In this model, natural habitats referred to forests and natural grasslands and rangelands (i.e., terrestrial habitats). Habitat loss, then, corresponded to the area of natural habitat projected to be replaced by human land uses such as urban, crop, and/or pasture. Below, we first describe the approach for identifying ABS by The Nature Conservancy; then the land use model and scenarios of future land use change used in this study; and finally the way that we use the ABS data and land use model to pursue four research objectives.

Areas of biodiversity significance

The identification of ABS is the result of a planning process by TNC called Ecoregional Assessments, used to guide regional biodiversity conservation in many places around the globe (Groves et al. 2002, 2003; see http://east.tnc.org/reports/all_assessments for examples in North America, Asia and Latin America). The objective of Ecoregional Assessments is to identify the ABS and inform potential conservation strategies for each ecoregion using the best scientific data and modeling tools available in conjunction with regional expert knowledge. The assessment includes several steps:

1. identifying the species and ecosystems that represent the biodiversity of the ecoregion (often focusing on rare and endangered, wide ranging, and keystone species, as well as key ecosystems, as a “coarse-filter” to capture common species and communities and the ecological processes necessary to sustain them);
2. setting conservation goals for the number and distribution of these targets;
3. assembling information on the location of conservation targets (such as maps of occurrences of species, natural communities, and ecosystem classifications);
4. evaluating the relative condition of the conservation targets (using information such as maps of, land use/cover data, existing managed and protected areas);
5. designing a network of ABS composed of the best remaining examples of targets that most effectively and efficiently meet abundance and distribution goals, often through using spatial optimization software such as Marxan (Possingham et al. 2000); and
6. identifying pervasive threats to address through conservation actions and potential sub-areas for priority actions.

During the Ecoregional Assessment process for the U.S., information about threats to ABS was in most cases based on expert opinion and literature review, and spatially explicit models to quantify future threat from land use were not commonly available (J. Higgins, *personal communication*). In addition to natural habitats, ABS may include some presence of crop and pastures with great value for restoration. We used the map of ABS for terrestrial and freshwater biodiversity from TNC as of August 2012.

Land use model and scenarios

The land use model by Radeloff et al. (2012) projects fine-scale land use changes between 2001 and 2051 for the conterminous U.S. under alternative policy scenarios, for different land use classes on private lands (i.e., urban, forest, crop, pastures and natural rangelands), based on observed landowner decisions in response to changes in economic conditions. The model is based on observations of 1990s land-use changes from the U.S. National Resource Inventory (available online at <http://www.nrcs.usda.gov/technical/NRI>; Nusser and Goebel 1997), together with county-level measures of economic returns to each land use from Lubowski et al. (2006), and information about soil quality, as a surrogate of agriculture potential. The economic return is the annual value of commodities produced minus the production costs, or in the case of urban land the rental value of the land absent any structures. For each combination of initial land use, soil type, and county, the model quantifies the probabilities of changes in private land use at 100-m resolution as a function of economic returns to the different land uses, and the costs of converting from one land use to another. Because the predictions from the model were based on probability values and there is uncer-

tainty at the 100-m pixel level, the results are not suited to show land conversion at the pixel level, but rather to quantify land use changes for larger areas such as ecoregions (as in Radeloff et al. [2010]), buffers around protected areas (as in Hamilton et al. [2013]), or, in our case, areas of biodiversity significance. The model parameters were estimated with data from the 2001 National Land Cover Dataset (2001 NLCD) and soil capability from the U.S. Soil Survey Geographic (SSURGO) database. Public lands (extracted from the U.S. Protected Database), were assumed to remain in the same use during the projection period, because the NRI does not measure land use change on federal land. Similarly, we assumed no changes in areas of wetlands, inland waters and natural barrens and rocks.

For the analysis presented here, we made several modifications to the model presented by Radeloff et al. (2012). First, we made economic returns to all uses endogenous using price elasticities that measure the percentage change in price for a one percent change in the quantity of commodities produced (e.g., crops, timber), following Lubowski et al. (2006). These price changes then affect economic returns and incentives for land use change. For example, if cropland expands in the future, this will increase the quantity of agricultural commodities supplied, reducing crop prices and economic returns to cropland.

Second, we altered the land use scenarios from those examined in Radeloff et al. (2012) to incorporate a more varied set of potential policies and outcomes. We simulated the effects of alternative policies by introducing subsidies and taxes affecting the economic returns to different uses. This produced a series of alternative scenarios in addition to a baseline scenario representing “business as usual” conditions (i.e., no new subsidies or taxes other than those present when the data to develop the model were collected). For this paper, we investigated three alternative policy scenarios:

1. an *Avoided Deforestation Scenario* that imposed a US\$100/acre tax for land leaving forest and reflects the implementation of a REDD-type policy (REDD = Reducing Emissions from Deforestation and Forest Degradation);
2. a *High Crop Demand Scenario* that assumed a 2% annual increase in all crop prices while maintaining all lands in the Conservation Reserve Program; and
3. an *Urban Containment Scenario* that allowed urban expansion only in metropolitan counties, as a proxy for strict smart-growth zoning regulations.

The 2% annual increase in crop prices assumed in the High Crop Demand scenario was chosen to reflect typical increases in crop prices that have occurred historically during boom periods. These scenarios provide a large range of potential future outcomes in order to explore impacts of future land use changes on ABS in the U.S.

Research objectives

Objective 1: Quantify current land use in ABS.— We extracted current land use from the 2001 NLCD. We used 2001 as the current condition in order to be consistent with the time-period covered by our land use projections (2001–2051). Within the total ABS, we summarized the total area (km²) of natural habitats -including forest and range, human land uses -including urban and crop/pasture lands, and water and wetlands (which we did not model into the future). In addition, we used the Protected Area Database to quantify the extent of public vs. private lands within ABS.

Objective 2: Quantify future habitat loss in ABS using an econometric model, for a business-as-usual and different policy scenarios between 2001 and 2051.— We used the land use model to quantify the total area of natural habitat within ABS predicted to be replaced by human land uses, under the different scenarios (Business-as-usual, Avoided Deforestation, High Crop Demand, and Urban Containment). We distinguished between future losses of forest versus range habitats, to identify the type of habitat affected by future land use changes, and calculated the percent habitat loss relative to 2001 amounts. In addition, we distinguished between habitat loss caused by urban development versus crop and pasture expansion, to distinguish different land use pressures on ABS. For the purpose of this study, we did not measure habitat gains resulting from the potential conversion of land uses into natural vegetation, as our goal was to evaluate land use

Table 1. Current land use (top) and land ownership (bottom) in entire Areas of Biodiversity Significance (ABS) of the United States.

| Land use/land ownership | Area in km ² | Percentage of the entire ABS area |
|-------------------------|-------------------------|-----------------------------------|
| Forest | 819,339 | 32 |
| Range | 1,063,717 | 42 |
| Crop/pasture | 290,491 | 11 |
| Urban | 85,400 | 3 |
| Water/wetlands | 298,890 | 12 |
| Privately owned | 1,566,766 | 61 |
| Publically owned | 991,071 | 39 |
| Total ABS area | 2,557,837 | 100 |

impacts on the original natural habitats identified within ABS.

Objective 3: Evaluate regional differences in habitat loss across the nation's ABS.—We quantified future habitat loss for the ABS of each ecoregion to compare rates of habitat loss among ABS and among scenarios. We also quantified the amount of habitat loss to urban versus crop/pasture for each ecoregion, to depict the geographic distribution of land use forces.

Objective 4: Identify regions where ABS are likely to be threatened by future land use changes.—Ecoregions where ABS faced substantial loss of natural habitats under all scenarios were considered to be potentially threatened. For the purpose of this paper, we defined “substantial habitat loss” if the projected rate was greater than 15%. This threshold was selected to facilitate the comparison among scenarios, corresponding roughly to the top 20th percentile of the habitat loss values observed across ABS in the business as usual scenario.

RESULTS

Current land use in ABS

The total ABS covered 2.6 million km² or 33% of the conterminous U.S. Natural habitats (i.e., forests and natural rangelands) were the most common land use within ABS (74% cover), and most of the land within ABS was privately owned (61%). Only 14% of the land was covered by human land uses, i.e., crop/pasture or urban (Table 1). However, there were also strong regional variations in land use within ABS across the country. In ecoregions of the West, ABS units were typically larger and located mainly in publicly owned lands, while in the East ABS units were typically smaller and located in

private lands (Fig. 1). At the same time, ABS in the East also included areas of crops and pastures (in the Upper Midwest) and wetlands (in the Southeast), which were rare in the West (Fig. 1).

Future habitat loss in ABS

Under Business-as-usual conditions, a total of 128,000 km² of natural habitats were predicted to be replaced by urban and crop/pasture land uses, equivalent to a 7% habitat loss. The other scenarios showed small deviations from the Business-as-usual, with the greatest rate of habitat loss predicted under High Crop Demand (8%) and the lowest under the Urban Containment (5%). In terms of the natural habitats, we did not find major differences between the rate of forest loss and the rate of range loss (Table 2).

In all scenarios, the expansion of both urban and crop/pasture lands were projected to replace substantial amounts of natural habitats in ABS, yet the expansion of these land uses affected forest and range habitats in different ways. Under Business-as-usual conditions, for example, urban and crop/pasture lands were projected to replace approximately equal amounts of forest habitat (~30,000 km²). For range habitat, however, future loss due to crop/pasture expansion was three times larger than that due to urban expansion (~52,000 km² vs. 16,000 km²; Table 3). The High Crop Demand scenario, on the other hand, increased the amount of habitat loss to crop/pasture by 40–50% compared to the Business-as-usual, while the Urban Containment scenario reduced the amount of habitat loss to urban expansion by a half. Finally, the Avoided Deforestation scenario had little effect on the rate of habitat loss, showing only a 5% reduction in the amount of forest loss predicted under Business-as-usual conditions (Table 3).

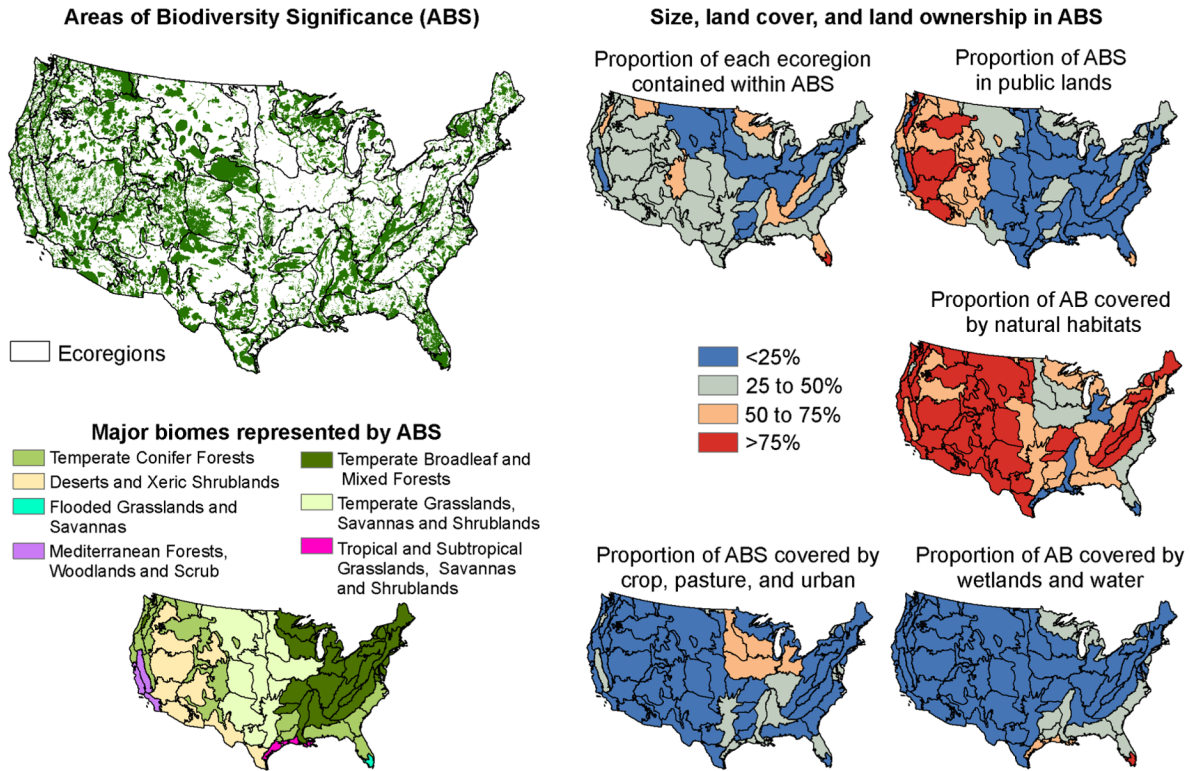


Fig. 1. Geographic distribution and land use characteristics of the Areas of Biodiversity Significance (ABS) in the United States. Data sources included the Nature Conservancy (for the limits of ABS, ecoregions, and description of biomes), 2001 National Land Cover Data (for the abundance of land cover classes within ABS), and Protected Area Database (PAD-US; for the abundance of public and private lands).

Regional differences in habitat loss

Our predictions showed strong regional variations in future habitat loss within ABS, ranging in value from 0 to 30% habitat loss depending on the regions, but typically increasing towards the East (Fig. 2 top). In general, the greatest rates of habitat loss (>15%) corresponded to ABS in the Southeast and South-Central U.S., some regions of the Upper Midwest, and in some valleys of the Pacific Northwest. A large cluster of ABS in the

western part of the U.S. showed little changes in the amount of natural habitats.

The different scenarios had a regional component as well. Compared to Business-as-usual, the High Crop Demand scenario increased the rate of habitat loss in ABS for the Midwest, Southeast, and California (Fig. 2 top). The Urban Containment, on the other hand, reduced the rates of habitat loss in ABS for much of the eastern U.S., yet with little effect in the West. In terms of total

Table 2. Future habitat loss (2001–2051) in entire Areas of Biodiversity Significance, under alternative policy scenarios of future land use change.

| Type of habitat | Area of habitat loss | | | | | | | |
|-----------------|----------------------|-----|-----------------------|-----|--------------------|-----|--------------------|-----|
| | Business-as-usual | | Avoided Deforestation | | High Crop Demand | | Urban Containment | |
| | (km ²) | (%) | (km ²) | (%) | (km ²) | (%) | (km ²) | (%) |
| Forest | 59,987 | 7 | 58,615 | 7 | 66,752 | 8 | 39,326 | 5 |
| Range | 68,032 | 6 | 68,382 | 6 | 92,989 | 9 | 58,835 | 6 |
| Total habitat | 128,020 | 7 | 126,997 | 7 | 159,741 | 8 | 98,161 | 5 |

Table 3. Future habitat loss (in km²; 2001–2051) due to urban or crop/pasture expansion in Areas of Biodiversity Significance under alternative policy scenarios of future land use change.

| Type of habitat loss | Area of habitat loss | | | |
|------------------------------------|----------------------|-----------------------|------------------|-------------------|
| | Business-as-usual | Avoided Deforestation | High Crop Demand | Urban Containment |
| Total habitat loss to urban | 48,174 | 48,323 | 44,157 | 19,217 |
| Total habitat loss to crop/pasture | 79,846 | 78,674 | 115,584 | 78,944 |
| Forest loss to urban | 32,157 | 32,253 | 28,585 | 13,519 |
| Forest loss to crop/pasture | 27,831 | 26,362 | 38,167 | 25,807 |
| Range loss to urban | 16,017 | 16,070 | 15,572 | 5,699 |
| Range loss to crop/pasture | 52,015 | 52,312 | 77,417 | 53,137 |

area (km²), the greatest values of habitat loss typically corresponded to ABS in the South-Central U.S. (Fig. 2 bottom).

The drivers of future habitat loss also varied among regions. Our predictions showed, with a few exceptions, crop/pasture expansion causing the most habitat loss in ABS in the Central U.S., and both urban and crop/pasture driving habitat loss in the East (Fig. 3). Along the West Coast, urban expansion appeared as the main cause of habitat loss in ABS. At the same time, the drivers of habitat loss showed regional variations among

the different scenarios. For example, under the High Crop Demand, and particularly under the Urban Containment, much of the projected loss in natural habitats observed in the East was related to crop/pasture expansion, with less participation of urban (see Fig. 3).

Potentially threatened areas

Our predictions identified 14 ecoregions where future habitat loss within ABS was consistently high (i.e., >15%) across scenarios, thus representing ABS that are likely to be threatened by future

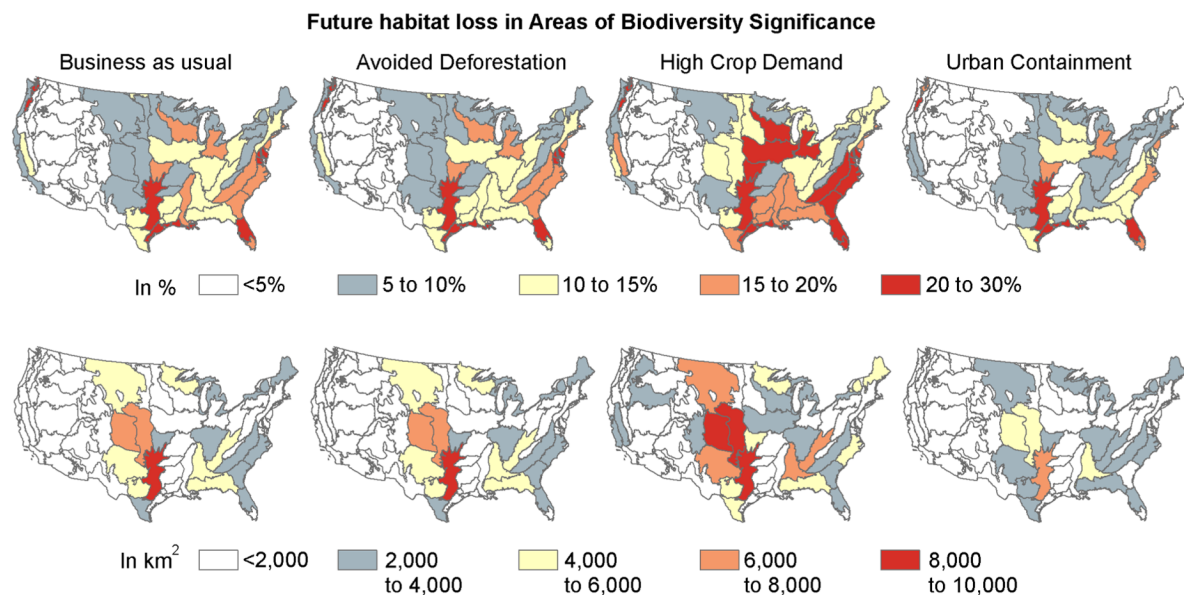


Fig. 2. Predicted habitat loss within Areas of Biodiversity Significance (ABS) for the period 2001–2051, by ecoregion, and under different scenarios of future land use change. The top section shows habitat loss in percent, while the bottom section shows habitat loss in km². For better visualization the maps display the entire ecoregion, but what is reported is the change within ABS in each ecoregion only. The term “habitat” includes forests and natural rangelands. An outlier with 43% habitat loss in one ecoregion was included in the category “20 to 30%” loss.

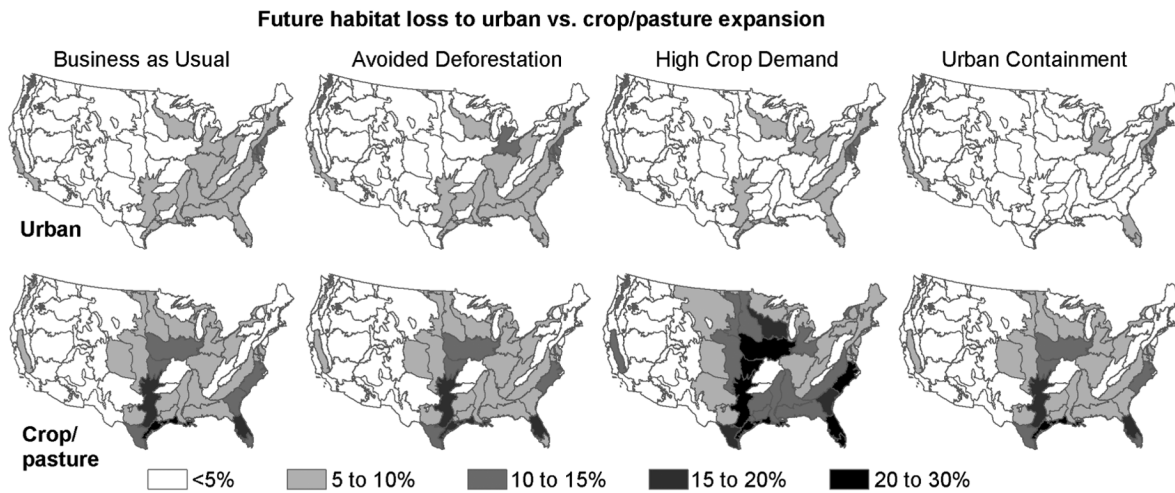


Fig. 3. Predicted habitat loss (in percent) due to urban vs. crop/pasture expansion within Areas of Biodiversity Significance (ABS) for the period 2001–2051, by ecoregion, and under different scenarios of future land use change. For better visualization the maps display the entire ecoregion, but what is reported is the change within ABS in each ecoregion only. The term “habitat” includes forests and natural rangelands. An outlier with 39% habitat loss in one ecoregion was included in the category “20 to 30%” loss.

land use changes. These 14 ecoregions (20% of total) were mainly located in the southeastern and South-central U.S., but also in the Upper Midwest, and in the Upper Northwest, and types of land use threat differed among them (Fig. 4).

DISCUSSION

Our study revealed that future land use change may pose important threats to conserve biodiversity in the United States because it may replace substantial amounts of natural habitats within Areas of Biodiversity Significance (ABS). Across all ABS, habitat loss from future land use is projected to be relative moderate (e.g., 7% under our baseline scenario), but land use has much stronger effects in some regions of the country (up to 30% habitat loss), and this is where conservation efforts will need to take future land use in to account to be effective. Land uses such as urban, agriculture and pasture have been long recognized as major threats to biodiversity (Noss and Peters 1995, Wilcove et al. 1998, Wilcove and Master 2005). Our study examined the pattern of future land use changes for multiple scenarios, relative to the patterns of ABS, and our results suggested that land use threats are likely to increase.

The use of scenarios is an important tool to advance environmental management under uncertainty, and allowed us to explore the potential impact of policies, zoning regulations, and changes in commodity prices (Polasky et al. 2011). We found that the total loss of natural habitats within ABS varied relatively little among scenarios (i.e., we projected a 5% to 8% total habitat loss depending on the scenario), but the effects of the scenarios varied greatly among ecoregions. For example, reducing urban sprawl (as simulated in our Urban Containment scenario) greatly reduced habitat loss in the East, where urban expansion is a major problem (Radeloff et al. 2005, 2010, Theobald 2010). In the central U.S., on the other hand, declines in natural habitat within ABS were considerably higher under our High Crop Demand scenario than under any other scenario. Overall, our study showed that the ABS in the U.S. are sensitive to future land use changes, and the implementation of land use policies, zoning regulations, or changes in commodity prices can affect ABS in some regions.

Threatened Areas

Our results identified a group of ecoregions where ABS may deserve priority attention for conservation actions. These areas encompass

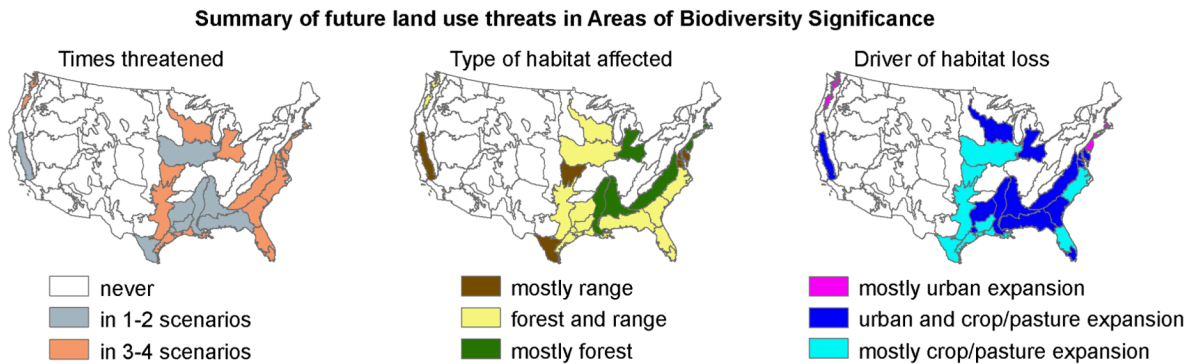


Fig. 4. Summary of land use threats on areas of Biodiversity Significance (ABS), by ecoregion, between 2001 and 2051. The map on the left show how frequent each ABS was threatened (i.e., number of scenarios). The other two maps show the type of natural habitat affected by future land use changes and the main driver of habitat loss, based on the Business-as-usual scenario. For better visualization the maps display the entire ecoregion, but what is reported is the change within ABS in each ecoregion only. For describing the types of habitat affected by future land use changes, we used “mostly range” if at least two thirds of the habitat area loss was in the form of natural rangelands, “mostly forest” if at least two thirds of the habitat area loss was in the form of forest, and “forest and range” if the proportion was balanced. The same approach was used for describing the drivers of habitat loss (i.e., “mostly urban expansion”, “mostly crop/pasture expansion”, and “urban and crop/pasture expansion”).

ABS in fourteen different ecoregions, concentrated in a few parts of the country, which exhibited substantial habitat loss in all or most scenarios. In the Pacific Northwest, for example, the ABS of the Willamette Valley ecoregion (formally Willamette Valley-Puget Trough-Georgia Basin Ecoregion) emerged as particularly threatened. The area is one of the most developed ecoregions in the Northwest and the majority of the natural habitats has already been lost or degraded (Nelson et al. 2008). According to the local Ecoregional Assessment, urban development is the main ongoing threat (Floberg et al. 2004). Our results concurred that this area is expected to experience more urban development and deforestation, thus potentially degrading even further. Therefore, limiting future urban growth within the ABS is an important task to protect biodiversity in the Willamette Valley.

ABS in the South-central U.S. contain some of the few remaining grassland ecosystems and are likely to be threatened by future land use changes. The local Ecoregional Assessments identified agriculture and pasture conversion as the largest threats to biodiversity conservation, followed by overgrazing, shrub encroachment, and urbanization (The Nature Conservancy

2000a, 2009). Our study indicated that, indeed, ABS in the southern grasslands may experience significant losses from pasture and agriculture expansion, especially if crop prices rise (our High Crop Demand scenario). We also predicted habitat loss to urban development in this region, which was substantial, but not as widespread as increases in crops and pastures. However, urbanization can have a disproportionately large effect on biodiversity relative to the area of urban land (Hansen et al. 2005) and therefore the projected changes in urban land in the region may also threaten the ecological integrity of its ABS.

Another group of threatened ABS was located along the East Coast. According to the Ecoregional Assessments for these areas, there are numerous threats to biodiversity, but land use is the main one (The Nature Conservancy 2001, 2002, 2005a, b, Samson and Anderson 2003, Anderson et al. 2006). Both urban and crop and pasture emerged as future threats in the regions from our projections, but the level of threat was significantly reduced under the smart-growth scenario (our Urban Containment). This suggests that actions towards reducing urban sprawl in the eastern U.S. could have a positive effect for conserving ABS.

The last group of threatened ABS was located in the Upper Midwest, including the Prairie-Forest Border and the North Central Tillplain ecoregions. The Ecoregional Assessments identified land development and agriculture as the greatest threats (The Nature Conservancy 2000b, 2003), and our results concurred that these two land uses indeed will continue to negatively impact the remaining natural habitats.

The fact that these ABS emerged as threatened in all or most socioeconomic scenarios suggests that reverting current land use trends in these areas may not be a simple task and may need the combination of different conservation approaches and close collaboration among key players (e.g., Doremus 2003, Bengston et al. 2004, Wilson et al. 2007). Such approaches include land acquisition, easements, improved management of government lands, and policies that support sustainable management practices on private lands. In this sense, conservation easements can tackle different potential threats and have become the primary tools used by public entities and private organizations for conserving biodiversity on private lands to address land development or agriculture, including by TNC (Fishburn et al. 2009a, b, Pocewicz et al. 2011). Easements protect land use and cover or restore it for a defined time frame (generally long-term) or can be permanent. This allows their contribution to securing and restoring land use or land cover over time to be evaluated in a quantified manner. Management and policy approaches can provide great ecological benefits, but do not necessarily change land cover or land uses. Although our data are too coarse to identify specific patches of land that should be targeted for potential acquisition, easement, or changes in management, they are useful to guide biodiversity conservation strategies at regional scales, and support future ecoregional planning efforts.

Finally, the ABS in California did not emerge as threatened using our approach, yet this region may also deserve special attention. The reason is that California supports the only Mediterranean-type ecosystems in the U.S., one of the most threatened biomes in the world (Sala et al. 2000), and our projections showed about 3,700 km² (7%) of habitat loss in the region. These findings are important because future climate change is already recognized as a major threat for conserv-

ing biodiversity and endangered habitats in California (Riordan and Rundel 2009, Wiens et al. 2011), and additional land use change may make conservation even more challenging here (Underwood et al. 2009).

Limitations

As any model-based investigation, our study has some limitations. For example, we used the area (km²) of habitat loss as the only indicator of land use threat. Such information is useful as an initial assessment, and future efforts may also evaluate potential changes in habitat fragmentation, connectivity and landscape context, which are important variables for assessing the impact of land use change on biodiversity (Fahrig 2003), but which our econometric model could not predict accurately (Radeloff et al. 2012). We suggest that our estimates based on area alone should not be the only consideration for conservation planning. In addition, our model did not differentiate among natural forests, managed forests, and plantations, and as a result, we were not able to identify potential threats that may arise from changing forest management practices, which can be particularly important in the Southeast (The Nature Conservancy 2001, 2002, Wear and Greis 2002). Furthermore, our land use model did not consider changes in wetlands (i.e., the area of wetlands stayed constant for the period of study). This is important because wetlands are an important feature in ABS of some ecoregions in the East coast, and Theobald (2010) indicated that U.S. wetlands will be impacted by future housing growth. As a result, the potential impact of future land use change on wetlands within ABS remains uncertain. Advances along these lines, including also the comparison with other sources of future land use data (e.g., Sohl et al. 2012), will improve our understanding of future landscape changes within ABS, and the potential consequences for biodiversity and conservation. These actions may include also evaluating the potential addition of habitats (we focused on loss), and exploring other policies. For instance, a policy that favors afforestation could provide opportunities for the expansion of forest habitats in/around ABS. Finally, comparison of our results with those from Radeloff et al. (2012) should be done with caution, due to differences in scenarios

and focal areas (i.e., ABS vs. entire ecoregions). For example, while Radeloff et al. (2012) examined an afforestation scenario, which included subsidy payments for new areas of forest, we examined here an avoided-deforestation scenario, where no such subsidies were provided, because our focus here was on habitat loss.

Concluding remarks

One of the main challenges of conservation planning is to understand the dynamics of future land use threats, including the potential outcomes arising from different policies and management decisions (Pressey et al. 2007). Despite the aforementioned limitations, our study provides manager and conservationists with new information about the patterns of future land use threats (i.e., where and what), which are critical to support decisions in ABS (Wilson et al. 2005, Pressey et al. 2007). Specifically, our results indicated that future conservation efforts should try to limit, mitigate, or at least be aware, of the projected expansion of urban areas and crop and pasture lands in ABS. Furthermore, our study showed that policies and zoning regulations applied at a national scale, as well as changes in commodity prices, can have notable impacts in some regions, as had also been reported by Radeloff et al. (2012). Ultimately, our study suggests that conservation actions (e.g., local, state level) will be critical to ensure that ABS can indeed protect biodiversity across the conterminous U.S.

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