Quantification of Habitat Potential for Biodiversity in the Field to Market Metrics

Final Report

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STUDY COMPLETION DATE: **Draft September 19, 2013**

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LABORATORY PROJECT ID: Report Number: N/A
Waterborne Study Number: 539.01

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STATEMENT OF DATA CONFIDENTIALITY CLAIMS

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GENERAL INFORMATION

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Study Dates

Phase I Study Initiation Date: August 1, 2012
Phase I Study Completion Date: October 31, 2012
Phase II Study Initiation Date: March 1, 2013
Phase II Study Completion Date:

Retention of Raw Data

Data used to conduct these analyses are currently stored at the facility of Waterborne Environmental, Inc., 897-B Harrison Street, S.E., Leesburg, VA 20175. This information may be transferred to the sponsor, at a later date.

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Executive Summary

The Habitat Potential Index (HPI) for Biodiversity explores the potential impact of agricultural land use on habitat quality and quantity of production and non-production lands. It offers a qualitative estimate of the potential of a grower's farm to provide habitat for biodiversity. Biodiversity under the HPI includes a variety of native species and ecosystems that may be found on or near the farm – for example, plants, invertebrates (such as pollinators and other insects), birds, mammals, reptiles and amphibians, or fish. The HPI considers current land cover types present at the farm scale– including production lands and non-production lands – as well as the producer's management activities for each land cover type. Land cover types included in the HPI are crop production areas, forest, grasslands and savannas, wetlands, surface waters, and edge-of-field areas such as buffer strips. The approach is intended to promote practical protection and enhancement of existing on-farm habitat attributes, as opposed to the conversion of production area back to pre-agricultural conditions. The HPI approach emphasizes the ecological benefits afforded by effective stewardship of non-agricultural and agricultural land cover types. By design, best management practices and sound environmental stewardship incorporate relevant ecosystem services, including biodiversity.

The HPI is being developed as one of eight metrics for environmental sustainability within Field to Market's Fieldprint Calculator. The Calculator is an educational tool that enables the grower to explore relationships between management practices and a suite of outcomes including habitat potential, land use efficiency, water use efficiency and water quality, soil erosion and soil organic matter, and energy use efficiency and greenhouse gas emissions. When viewed collectively, this suite of metrics can provide a more complete picture of environmental sustainability performance as well benefits and tradeoffs associated with various practices. For example, while the HPI focuses on the overall impact of practices on habitat quality and quantity on the farm (e.g., land sharing), the land use efficiency metric provides insight into how increased productivity can reduce the need for land conversion elsewhere, and thus help conserve habitat potential off farm (land sparing). The Calculator serves as a starting place for the grower to look at his or her performance against all of the metrics and, working with local experts (for example, NRCS or University Extension), identify the most appropriate opportunities for improvement in both productivity and environmental performance within the specific context his or her own operations. The intent is to make the HPI available at the field and whole-farm level. Results to the grower would be provided on an individual land cover and aggregate farm basis, and would be compared to the maximum possible score based on the grower's current land cover types (rather than to external benchmarks and/or to alternative land cover conversion scenarios).[1]

[1] Appendix A provides summary slides that describe of the HPI objectives.

1.0 Introduction

1.1 Agriculture as a contributor to the conservation of biodiversity

The role of private agricultural land in the conservation of biodiversity has gained increasing recognition as providing an important supplement to existing and planned conservation areas (Batary et al. 2010, Polasky 2008, Dumanski and Pieri, 2000, UNEP 1997). Investment in research and incentives for adoption of conservation practices on agricultural lands is evidence of a paradigm shift in which biodiversity and agricultural production are no longer considered mutually exclusive, and growers are increasingly recognized for serving a critical role as good stewards of the land and their influence in environmental stewardship. Sustainability of agricultural ecosystems is defined by achieving a balance between ecological and economic considerations (Feld et al. 2003), and necessitates the development and application of integrated landscape planning approaches that can provide benefits both to ecosystems and landowners (de Groot et al. 2009, Power 2010). One key factor in balancing ecological and economic considerations is the identification of field and farm management practices designed to enhance not only agricultural productivity (yield), but also ecological productivity as well. Alternative crop production practices, for example conservation tillage and integrated pest management (Lindenmayer et al. 2007, Dumanski and Pieri 2000), and other strategies which promote diversification of cropping systems can contribute to achieving this balance. Additionally, the capacity for supporting biodiversity offered by non-production lands present at the spatial scale of the farm (defined for this project as a single continuous parcel of land), is a significant conservation opportunity for growers that should be acknowledged and leveraged wherever possible. Ideally agricultural areas should be evaluated holistically (Yi Vikarri, 1999), as the field-scale may not adequately represent the dynamics of biodiversity such as the fact that the significance of management activities may vary based on the spatial composition of the whole farm, as well as that of the larger landscape (Laterra et al. 2012, Batary et al. 2010, Gabriel et al. 2010, Bengsston et al. 2005). To address this complexity, Field to Market (The Keystone Alliance for Sustainable Agriculture) initiated research efforts to characterize optimal scenarios for the co-existence of agricultural production and biodiversity based on landscape attributes at the farm-scale in addition to the field scale (Field to Market, 2012).

1.2 Rationale for a Habitat Potential Index (HPI) approach to address biodiversity

This report describes the development of a land-cover based approach for estimating habitat potential as a proxy measure to address biodiversity (abundance and diversity of native species and ecosystems) for agricultural systems at the farm scale. The Habitat Potential Index (HPI) for biodiversity proposed in this study addresses and quantifies the ecological benefits of land management practices (current and future), emphasizing effective stewardship of both non-agricultural and agricultural land cover types. The approach highlights protection and preservation of existing land cover/habitat as well as a rationale for intensification of cultivated areas to mitigate further loss or degradation of habitat. Best management practices and sound environmental stewardship incorporate relevant ecosystem services, including biodiversity, to various extents depending upon the practice. The quantification of habitat potential was developed based on the following criteria: land cover types within U.S. ecoregions, farm land cover composition, and land management intensity. Consideration of attributes of the agricultural landscape including pattern, extent, and management intensity enables the characterization of the habitat potential afforded by agriculture and helps identify means to improve. The basic assumption underlying the HPI approach is that habitat degradation and loss (e.g., fragmentation) are primary factors influencing biodiversity (Haines Young 2009, Opdam and Wascher 2004). This assumption underlies the use of land cover structure, function, and related dynamics (land use change, management activities) of production and non-production areas as an indirect indicator of biodiversity. The scientific rationale for extrapolating a biodiversity measure based land cover attributes as opposed to relying heavily on outcome-based biological response measures (such as prediction of individual or groups of species) is discussed in further detail later in this Introduction. As a practical matter, the use of the HPI as an indirect measure of biodiversity avoids the complexity and data gaps that can present challenges for approaches that require detailed species enumeration.

In developing the HPI approach, one of the main objectives was to design a tool based on scientific principles that is also achievable, practical, scalable, and agronomically-grounded (Appendix A). This implies that a balance must be realized between scientific defensibility and simplicity, and correspondingly a balance between addressing the complexity of assessing biodiversity while keeping focus on what is useful from the perspective of a grower. Of particular importance is the ability to characterize and communicate biodiversity benefits of well-managed agricultural lands without creating any additional regulatory burden for producers. The integration of existing, recognizable and accepted approaches in the development of the HPI is one way this issue is addressed. Additionally, given the variety of trade-offs inherent with an issue as complex as the conservation of biodiversity on agricultural lands, the leveraging of existing strategies may better enable stakeholders to find "common ground" in the reliance on (and/or alignment with) widely recognized existing approaches. For example, the landscape accounting approach at the core of the HPI is similar to the established approach used by the National Resources Conservation Service (NRCS, USDA) for assessing ecological benefits of conservation programs. The ecological-quality scoring scheme (discussed later) is roughly based on the habitat suitability index approach used by U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. Additionally, overlap of many of the inputs of the HPI tool with the existing Fieldprint Calculator and upcoming Water Quality Index metrics by Field to Market point to a practical relationship between these tools; for example, many components of the HPI were refined to create the potential for information from existing Field to Market metrics to be imported to limit the effort level required by the grower using these tools.

Phase I of this project, initiated in August of 2012, encompassed the preliminary development of a HPI approach based on a review of the literature related to existing approaches for assessing biodiversity and the compilation and preliminary definition of the land cover-based framework by which a semi-quantitative representation of habitat potential (and indirectly, biodiversity) could be established. Incorporated within the timeframe of Phase I were three formal feedback opportunities during which input from the Field to Market Biodiversity Subgroup was collected. These interactions included three conference calls where progress on the development of the HPI approach was presented and discussed by the subgroup. The outcome of Phase I resulted in the development of a technical subcommittee, comprised of a smaller subset of Field to Market Biodiversity Subgroup members representing a variety of expertise and stakeholder perspectives, charged with identifying and addressing needed refinements to the Phase I approach during a workshop in March of 2013.

Specific goals of Phase I included:

1. Identifying relevant land cover types comprising the basis of the HPI and determine "ecological weighting factors" associated with them

2. Defining preliminary farm-scale HPI parameters and associated algorithms specific to relevant land cover types

3. Identifying and develop options for benchmarking HPI

4. Initiating development of a “mock-up” tool

Specific goals of Phase II included:

1. Workshop for a technical subcommittee from the Field to Market Biodiversity Subgroup to review and identify needed refinements from Phase I (held March 6-7 at NC State in Raleigh, NC)

2. Revisions to Phase I approach and report based on technical subcommittee recommendations

3. Creation of a functional spreadsheet tool upon acceptance and finalization of HPI approach to enable beta testing prior to web integration

The consensus gathered during Phase I and the technical subcommittee workshop in Phase II was intended to provide the groundwork for further refinement and functionality of the HPI approach as a Field to Market metric for biodiversity. The specific components of the HPI, including their scientific basis, use of existing tools and/or methodologies, and relevance as a biodiversity proxy based on information accessible and intuitive to a grower at the farm-scale, are provided in this report and the accompanying Appendices.

2.0 Literature review

2.1 Defining and predicting biodiversity: biological outcomes vs. driving factors

Biodiversity can be defined as "the variety of taxonomic, functional and genetic characteristics of life" (Feld et al. 2003) including plant and animal communities as well as ecosystems which represent homogenous combinations of each. Common measures of biodiversity for conservation planning focus on biotic attributes represented in measures such as total species abundance (richness), metrics such as the Shannon Weaver or Simpson indices, or species abundance focusing on specific keystone species or umbrella species assumed to be representative of the total population of species in a given area (Feld et al. 2003, Carigan and Villard 2001). Other indicators of biodiversity include the status of "at-risk" species for a given spatial unit, which focuses on species considered vulnerable to extinction using classifications such as the World Conservation Union (IUCN) Red List, NatureServe conservation status, and the U.S. Fish and Wildlife threatened and endangered classification (Flather et al. 2003). These biotic measures provide a literal characterization of biodiversity from a taxonomic and genetic standpoint, but have a number of limitations. Species richness is subject to natural variability across taxonomic groups, and therefore the use of species richness as a measure for representing biodiversity requires accounting for this complexity in data collection, organization and analysis (Flather et al. 2003). Biotic indicators of biodiversity are most accurate at the local scale, but become less representative when extrapolated to larger geographic areas or different regions (YiVikarri 1999, Billeter et al. 2008). Andelman and Fagan (2000) found that the usefulness of keystone, umbrella, and flagship species as surrogates for biodiversity was limited as it was observed that results using these selected species did not differ significantly from those generated using randomly selected assortments of species. Variability in significant spatial and temporal processes can further complicate the use and interpretation of biotic measures of biodiversity. For example, observed species occurrence at the local scale may be most influenced by factors operating at larger scales (e.g., land use pressures at the landscape scale, migratory patterns, climate change) and may also exhibit a time lag between land management actions and subsequent changes in species distribution, resulting in a potential mismatch of management-response relationships (Gabriel et al. 2010, Feld et al. 2003).

Biodiversity is often characterized as having intrinsic value based on the conservation of biological attributes of the environment (Koschke et al. 2012, Burkhard et al. 2009). However, it has been suggested that biodiversity (and its associated indicators) should incorporate a more holistic definition that captures not just specific biotic outcomes (genetic and taxonomic abundance), but also the ecological processes that are intrinsically linked to biodiversity as both an associated outcome and a requirement, and which ultimately are often more relevant to conservation purposes (Mace et al. 2012, Haines-Young 2009, Andreason et al. 2001, Noss et al. 1990). The concept of ecosystem services has been increasingly explored and applied as a more holistic conservation goal (e.g., Mace et al. 2012, Galic et al. 2012, Laterra et al. 2012, Power 2010) that is closely related to biodiversity but often more relevant to practical sustainability performance measures, such as energy flow and nutrient cycling. While ecosystem services and biodiversity are inherently related, it remains difficult to develop a quantitative linkage between them, and moreover to establish linkages between ecosystem services and management practices that may influence them (Mace et al. 2012, de Groot et al. 2009). Due to these uncertainties, greater potential for success may exist in the development of biodiversity indicators representing structural and functional aspects of ecological integrity (i.e. quality) which support ecosystem services and are more directly quantifiable (Burkhard et al. 2011). Ecological quantity and quality (structure, function), as well as the management practices that influence both, can therefore serve as a meaningful proxy for directly measuring biodiversity (UNEP 1997). These attributes can be represented by landscape measures (based on land cover) that have demonstrated a quantifiable link with biodiversity (Frank et al. 2012, Billeter et al. 2008, Bailey et al. 2007, Feld et al. 2003) as well as relevance to ecosystem services. This type of approach, which provides the fundamental basis of the HPI approach in this study, is consistent with the assumption that land cover and land use change (i.e., habitat loss) is ultimately the driving factor of the status and trends in biodiversity (Haines-Young, 2009).

2.2 Recent approaches for developing indicators for biodiversity (review)

A number of recent approaches for evaluating biodiversity at the field, farm, or larger landscape scale were reviewed in order to investigate how others have addressed this issue and to identify areas of strength and lessons learned to better inform the development of the HPI. The studies evaluated span three major areas of focus to varying degrees, from biologically-focused assessments based on habitat patterns and likelihood of species occurrence, approaches focused on assigning ecological weight to various specific management practices, and land-cover based approaches assigning ecological weight to specific land cover types (**Figure 1**). Recent studies by North Carolina State (Drew et al. 2012) and Polansky et al. (2008) are examples of different biodiversity characterizations driven by information on local species ranges and habitat preferences specific to a regional study area. In the NC State pilot effort (jointly funded by Field to Market and The Nature Conservancy), probability of species occurrence of approximately 250 species (organized by "sensitivity traits") was estimated through the systematic collection of expert opinions which were used as input for the development of probabilistic responses of species occurrence to field-scale conditions and practices. The resulting metric provided output directly relevant to biodiversity by estimating a biological measure (i.e., species occurrence). Species-based approaches can involve a relatively high degree of study area specificity that can make extrapolation to large geographies a challenge (Feld et al. 2003). These approaches also require a significant level of effort for the organization and attribution of species preferences across large geographic areas, compilation and characterization of expert responses (e.g., NC state study), or geoprocessing requirements to generate habitat measures (e.g., Polansky et al. 2008 study). Management activities may also be used as the primary (or single) attributes for inferring biodiversity and associated ecological quality. The National Resources Conservation Service (NRCS, UDSA) has devoted a great deal of resources to developing, researching and

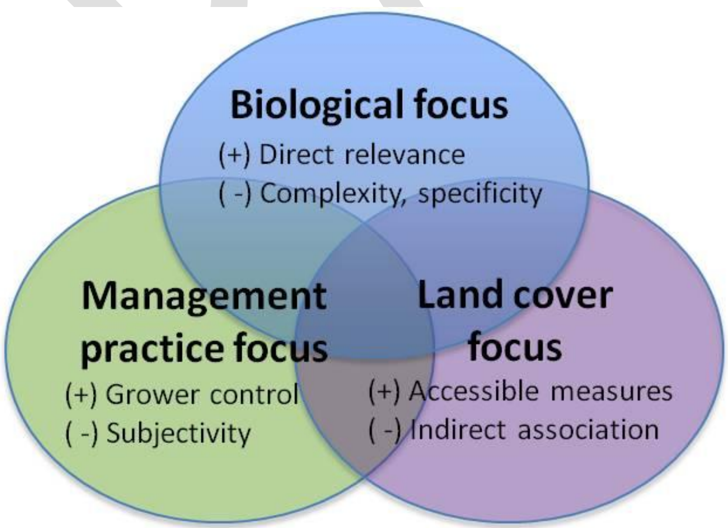

Figure 1. Schematic of different focus areas for development of approaches for evaluating biodiversity, with pros and cons for each.

assessing performance of various alternative agricultural management practices designed to improve or maintain structural and functional components important to biodiversity as part of a variety of conservation incentive programs (http://www.nrcs.usda.gov). The NRCS Conservation Measurement Tool scoring system, a component of the NRCS Conservation Stewardship Program, assigns a numeric scoring system to various conservation practices based on environmental benefits offered by a given practice, the sum of which can be called the Environmental Benefits Score ("EBS") for a given practice ("EBS" term used by National Coalition for Sustainable Agriculture, http://sustainableagriculture.net). This NRCS scoring provides an assessment of the relative ranking of conservation practices to one another which can guide management decisions based on achieving the greatest benefit to local ecological condition. The biodiversity metric in development by the Stewardship Index for Specialty Crops (http://www.stewardshipindex.org/) has a strong focus on a selection of best management practices for both cropped and non-cropped areas. Grower surveys and assessments with a strong management focus can provide valuable information about details of farm operations relevant to biodiversity. A challenge of management-focused surveys is to simplify options to practices demonstrating both high ecological relevance and that are relatively well-known to growers.

A number of approaches have utilized a land cover-based strategy where the influence of various land cover types and associated management strategies on biodiversity have been characterized in order to assess current and future scenarios of land use status. The concept of "high nature value farmland" in Europe (Anderson et al. 2004, Sullivan et al. 2010, Parracchini et al. 2008, Pointereau et al. 2007) applies to agricultural land with high potential to sustain biodiversity, and has been described from a land-cover perspective based on expert-ranked weights for various land cover types (Anderson et al. 2004). Similar to the expert-based ranking of land cover in the delineation of high nature value farmland, Burkhard et al. (2009) used expert assessment to create a matrix of ecosystem services supported by different land cover classifications (CORINE) across Germany. While land cover evaluated in this approach included a variety of cropping systems, it did not incorporate variability in specific management practices beyond basic crop types; however, this approach allowed for mapping of ecosystem services based on easily measurable land cover patterns (Burkhard et al. 2009). A recent study by Von Haaren et al. (2012) introduced a farm-scale approach where rankings were assigned to biotopes (areas of homogenous ecological conditions) based on the relative measure of ecological importance (characterized by naturalness and rarity based on presence of threatened and endangered species), and within each biotope a sub-score was delineated based on conservation management, and this information was combined with a habitat connectivity analysis comparing biotope connectivity for a given farm with connectivity requirements for selected target species associated with the particular biotope (Von Haaren et al. 2012). The influence of different farm management practices was estimated for each biotope using relationships from the literature (not defined in the study), resulting in the assignment of a "risk" value to biodiversity that can be used to highlight management priorities for a given farm (Von Haaren et al. 2012). The NatureServe Vista tool *(*www.natureserve.org/vista) also incorporates a framework for expert-based ranking of land cover type by conservation importance (either as a conservation "element" to be protected or by its relative impact on other conservation elements such as particular species). While the concept of ranking ecological quality amongst and within biotopes provides a useful and simple approach for characterizing land cover patterns in terms their relevance to biodiversity, the integration with species-specific habitat preferences presents similar challenges to those described previously for approaches with a strong biological focus.

An alternative semi-quantitative scoring system to assess biodiversity based on land cover patterns and other attributes was demonstrated by Reidsma et al. (2006) for 100 sub-national regions across the EU. In that study, biodiversity was assessed using an ecosystem quality value based on agricultural and non-agricultural land use at the farm scale. Ecosystem quality, used to represent biodiversity, was defined as the mean abundance of native species within the current status of an ecosystem relative to their abundance in the ecosystem in "pre-disturbed" conditions using a pre-defined selection of species (Reidsma et al. 2006), with a value of 100% corresponding to maximum biodiversity (comparable to "pre-disturbed" conditions) and a value of 0% indicating a total loss of biodiversity. Ecosystem quality values were derived by dose-response-like relationships between land cover (or management intensity represented by information in the Farm Accountancy Data Network for over 50,000 farms) and biodiversity based on a review of available literature. Impacts of land use change could be estimated based on simulated scenarios converting a proportion of a land cover type to another and/or simulating a change in management intensity. Of all the approaches described, the Reidsma et al. (2006) approach is most similar to the HPI approach proposed in this current study, which similarly assigns ecological quality values to land cover types present within a given farm (both production and non-production areas) based on established relationships between land cover attributes, management practices, and biodiversity. However, a number of characteristics from other studies and existing approaches have been incorporated within the current HPI approach as well. The HPI approach is based on a framework in which each land cover present on a farm is assigned an ecological weight based on the relative ecological importance of the land cover using a naturalness and rarity gradient similar to that employed by Von Haaren et al. (2012). Information on the influence of management practices on biodiversity presented in other studies and applications (e.g., NRCS Conservation Measurement Tool scoring system, predicted operational decision impacts in NC State pilot) was used to inform the selection and representation of management practices within the components of the HPI.

3.0 Quantifying habitat potential: proposed methodology

3.1 HPI Overview

The HPI is a semi-quantitative scoring system for individual farms. The use of a semi-quantitative scoring system to generate an index, comparable to the HPI, has been demonstrated in other studies (see Reidsma et al. 2006, Von Haaren et al. 2012). The scoring approach is supported by narrative, qualitative, and quantitative algorithms that characterize the habitat potential of a farm incorporating all relevant land cover types (e.g., cropland, grassland/savanna, forest, ponds, wetlands, etc.) as influenced by farm management practices. Characterization includes a land cover quality assessment that considers: landscape structure and function, land management intensity, and land use change specified by the user for each defined land cover type. An efficient land-use pattern is one that generates the maximum HPI score for a given land cover type. By maximizing the land quality score over the defined range of possible land cover scores, an efficiency matrix for the agricultural landscape at the farm level can be characterized. There are three primary components of the HPI:

1.) ***Farm composition*** (acreage of various land cover types)

2.) ***Ecological weighting factors*** attributed to different land cover based on a relative scale of 1 to 5 based on the ecological quality of a given land cover ("naturalness" and capacity to support ecosystem services, similar to the concept of biotope rating in Von Haaren et al. 2012 discussed previously)

3.) ***Ecological quality values*** for each land cover type (scale of 0 to 10) based on an aggregated score (weighted average, described in Section 3 and accompanying Appendix C) of individual HPI parameters representing structural, functional and management characteristics of the land cover relevant to habitat potential.

HPI calculations can be summarized in different ways (discussed later in Section 3.6), depending on the specific objective. The following sections describe in detail the components of the HPI (Sections 3.2-3.5) and propose options for integrating the component information (Section 3.6) into meaningful metrics for evaluating habitat potential at the farm scale.

3.2 Characterization of land cover types

Fundamental to the development of the HPI approach was the identification of relevant land cover types for individual farms and the larger ecoregion or ecological province in which the farms are located. The initial work makes sequential use of existing broader scale descriptions of ecoregions and provinces from the US Forest Service. Ecoregions represent areas grouped by similarities in geology, physiography, vegetation, climate, soils, land use, wildlife distributions, and hydrology (e.g., Bailey ecoregions, http://www.fs.fed.us/rm/ecoregions/). Subcategories of major agricultural and associated ecosystem land cover types were defined for the HPI calculations (**Table 1**). The potential land cover types for a given farm can be generally categorized as "Cultivated areas", including land cultivated for agricultural production, and "Non-cultivated areas" including land cover not intensively managed for agricultural production such as grasslands, savannas, forest, wetlands, buffer features, and surface waters. Land covers were selected wherever possible to correspond with established geospatial land cover classifications in datasets such as the USDA NASS Cropland Data Layer and the USGS GAP Land Cover Dataset. Geospatial data representation of land cover types allows for use of these data resources for determining farm composition (possibly computed in the background by the final web-based tool, or simply as a reference for growers), as well as for potential future benchmarking purposes when evaluating land cover at state or other spatial scales. Additional land cover types were identified for inclusion by the technical subcommittee during the March 2013 Raleigh workshop including a variety of edge-of-field features that may be present on a farm.

Table 1. Land use/land cover types included in the HPI tool[2].

Land Cover	Options (Land Cover Types)
Cultivated land	Corn, Soybeans, Rice, Cotton, Potatoes, Wheat, Alfalfa/Hay, Other crop(s)
Edge features/ Riparian buffers	Buffer strips, Grass waterways, Terraces, Filter strips, Field borders, Pivot corners (uncultivated), Pollinator habitat, Hedge rows, Tree rows, Wind breaks, Headlands, Riparian buffer features
Forest	Conifer Plantation, Deciduous Forest, Evergreen Forest, Mixed Forest
Grassland/Savanna	Native (un-grazed), Native (grazed), Non-native (un-grazed), Non-native (grazed or hay)
Wetlands	Natural wetland, Artificial wetland
Surface waters	River, Stream, Pond (natural), Pond (artificial), Lake (natural), Lake (artificial)

[2] Additional description of the land cover types are provided in Appendix C.

The HPI methodology differentiates between natural and artificial wetlands. Artificial wetlands include constructed wetlands as well as "working wetlands" (also commonly classified as "moist soil units") resulting from the use of certain agricultural management practices such as winter flooding of rice fields which provides an ecological benefit for waterfowl (Manley eds. 2008, NRCS 2007). The characterization of rangeland presents a unique challenge as this land use type is not easily defined by geospatial data classifications. The USGS GAP Land Cover classification "Disturbed, non-specific" provides a potential option to geospatially define high-intensity grazed rangelands as the definition of this land cover notes that it is "*typically associated with heavy amounts of grazing*" (http://gapanalysis.usgs.gov/gaplandcover/); however most rangeland is categorized as grassland. In contrast to cultivated land cover, rangeland is typically managed more similarly to native vegetation (NRCS 2003). During the March 2013 workshop, the technical subcommittee determined rangeland would be appropriately included in the "Grassland" category, based on whether the land is subject to livestock grazing. At low-intensity grazing levels, the ecological benefits of rangeland are comparable to natural (un-grazed) conditions (Reidsma et al. 2006, Alkemade et al. 2010). To meet the challenge of representing rangelands in the HPI and to recognize the ecological significance of low-intensity rangelands (for which a landowner should receive more credit), input from the grower on relative grazing intensity will be used to influence the ecological weighting and the ecological quality score for grassland on a farm (discussed in Appendix C). As such, grassland with low-intensity grazing will have the opportunity to be scored similarly to un-grazed grassland.

3.3 Ecological weighting factors

Weights were assigned to the different land-use categories defined within the HPI estimator based on (1) general concepts of naturalness (e.g., Von Haaren et al. 2012), capacity to support ecosystem services, and regional landscape context, as well as (2) modifying factors determined by designation of important conservation areas (discussed shortly), and current development pressure (e.g., urban sprawl) to which a land cover may be exposed.

3.3.1 Base weights

Table 2 lists the base weights for the cultivated and natural ecosystem land-use types defined in the HPI methodology. These values are broadly defined in terms of the relative ecological value (i.e., ecosystem supporting services) associated with each land-use type, with more "artificial" or disturbed land cover types having lower eco-weights, and more natural land cover types having higher weights. Non-native and grazed native grassland/savanna, conifer plantations and artificial wetlands are given a base ecological weight of 2. One exception for artificial wetlands are seasonally flooded rice fields, which are assigned a higher ecological weight of 4 for farms in ecoregions generally corresponding with the Mississippi Alluvial Valley, the Gulf Coast, and the Central California Valley where seasonally flooded rice fields provide important habitat for migratory birds (State of the Birds 2013 Report on Private Lands http://www.stateofthebirds.org). Cultivated (agricultural) lands are assigned an ecological base weight of 1. This categorization scheme is consistent with previous classifications of land cover type by ecosystem quality in which cultivated land has a relatively low range of ecosystem quality compared with other systems (Reidsma et al. 2006). Wetlands, surface waters (streams, rivers, natural lakes and ponds) and riparian areas are assigned high base weights because of their structural complexity, productivity, diverse flora and fauna, waste assimilation, and biogeochemical cycling characteristics. Natural and restored wetlands are assigned the highest value (5) due to the extensive loss of these ecosystems and related biodiversity and ecosystem services (Fennessy and Craft, 2011).

Mixed forest, deciduous forest, evergreen forest and native grassland/savanna were assigned a base weight of 3 or 4 on an eco-regional basis, determined by the predominant land cover characteristics of the larger landscape. Landscape composition at a large regional scale was represented using land cover statistics for ecological systems from the USGS GAP Program available at the scale of "Landscape Conservation Cooperative" units ("LCC's" U.S. Fish and Wildlife Service, http://www.doi.gov/lcc/index.cfm). Ecoregional provinces were assigned to an LCC based on the LCC which contained the greatest proportion of their land area. The general

Table 2. Eco-weighting factors for land-use categories defined within the HPI estimator.

Eco-weight	Land covers
1	Cultivated lands
2	Non-native grassland/savanna, Grassland/savanna (grazed/hay), Conifer Plantations, Artificial Wetlands, Edge features, Lakes (artificial), Ponds (artificial)
3	Native Grassland/Savanna (un-grazed)/Forest less characteristic of ecoregion
4	Native Grassland/Savanna/Forest more characteristic of ecoregion, Rivers, Streams, Lakes (natural), Ponds (natural), Riparian Areas, Artificial Wetlands based on seasonally flooded rice in select ecoregions
5	Natural wetlands, Native Grassland/Savanna/Forest and Surface Waters in Conservation Priority Areas

approach (detailed shortly) was to simply score the native grassland/savanna and forest categories with an eco-weight of 3 or 4 on a per-ecoregion basis in terms of their predominance in the regional landscape. This approach significantly differs from the previous (Phase I) effort which emphasized relative scarcity of land use types in assigning scores. The justifications for emphasizing representativeness/predominance instead of scarcity in the revised scoring are (1) acreages that are common land cover types within an ecoregion are assumed to have a higher potential for species diversity characteristic of the ecoregion, (2) the representative or more common land-use types within an ecoregion are more likely to be contiguous with similar land-use types or serve as corridors - and correspondingly provide additional ecological value at the farm scale and surrounding landscape scale, and (3) the concept of scarcity/rarity is already accounted for in the modifying factors (described shortly) which identify and prioritize sensitive/rare ecosystems. Additionally, the quantitative derivation of scarcity scoring in Phase I was determined by the technical subcommittee to add an unnecessary level of complexity to the scoring, compared with a simple 3 or 4 score assigned in this revised approach.

The following approach was used to assign simple ecological weights of 3 or 4 to the native grassland/savanna and forest land cover categories based on ecoregion. The percentage of total grassland/savanna acreage (i.e., Shrubland & Grassland) for an LCC was compared to the percentage of total forested acreage (i.e., Forest & Woodland) for the LCC. If the percentage of grassland/savanna acreage was greater than forest, the LCC was assumed to be characteristically grassland/savanna, and a value of 4 was assigned to the native (un-grazed) grassland/savanna land cover category for ecoregions associated with that LCC. Conversely, if the LCC data indicated the landscape region to be predominantly forest, a value of 3 was assigned to native (un-grazed) grassland/savanna. The derivation of scores for the three forest types was similarly based on the percentage of acreages that broadly correspond to evergreen, deciduous, and mixed forest determined from the regional LCC land-use summaries. The relative importance of evergreen forest was primarily assessed using the relative acreage of the LCC Warm Temperate Forest. LCC summaries of Cool Temperate Forest were used to evaluate the relative importance of both deciduous and mixed forest. The predominant forest types were assigned a score of 4; the less common forest types were assigned a score of 3. The major subcategories of acreages reported for the individual LCC summaries were used to refine the analysis as appropriate for each region. This was particularly important in helping to assess and score the relative importance of deciduous and mixed forest types. Finally, the Bailey ecoregion descriptions for vegetation (http://www.fs.fed.us/land/ecosysmgmt/colorimagemap/ecoreg1_provinces.html) were used to ensure that the base eco-weighting factors derived by the LCC approach were consistent with the Bailey ecoregion descriptions for vegetation.

Base eco-weighting factors for land covers are provided by ecoregional province in Appendix B.

3.3.2 Modifying factors

While natural wetlands are considered of high ecological value from both an ecosystem service and ecological "scarcity" perspective in the HPI, it is also recognized that many areas of forest, native grassland/savanna and surface water resources provide comparable levels of ecosystem services and habitat. To address this issue, a modifying factor on the ecological weights is proposed where forest, native grassland/savanna and surface waters falling within the spatial coverage of U.S. "Conservation Priority Areas" (The Nature Conservancy, http://uspriorityareas.tnc.org/) are assigned the highest ecological weighting factor of 5 (**Figure 2**). This approach would take advantage of an existing measure of ecological value developed by The Nature Conservancy that identifies geographic areas comprising important habitat for rare and endangered species, are considered rare, threatened or highly sensitive ecosystems, or have other attributes relevant to conservation such as providing landscape connectivity for specific habitat types. Use of this modifier will be dependent upon granted use of the spatial data by

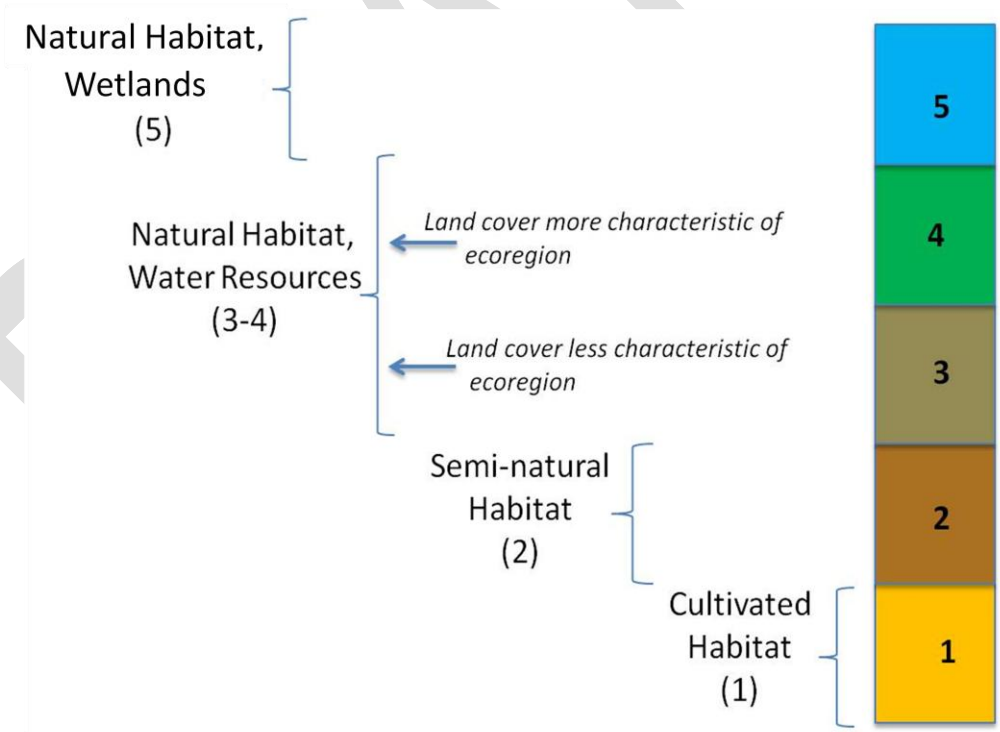

Figure 2. Illustration of gradient of ecological weighting values comprised of base weights (moving upward based on ecological quality as defined by degree of naturalness and potential for ecosystem services)

request to The Nature Conservancy (TNC), and would be determined in the background by the HPI tool based on the geographic location of the farm (location information may be imported from the Fieldprint Calculator). Geospatial habitat ranges of threatened and endangered species (NatureServe) may also be used in addition to TNC "Conservation Priority Areas" to ensure that important habitat is included in the eco-weighting; however, the level of effort required to integrate the raw NatureServe data may limit the practicality of using this additional element.

A final additional proposed modifying factor for the eco-weighting is related to land cover change is the relative "threat" of urban development (i.e. urban sprawl) in the vicinity of a farm based on recent land use trends, which provides a relative measure of risk to the local ecosystem (Rodrigez et al. 2007). An additional 0.5 will be added to the eco-weight of a given land cover (up to a maximum eco-weigh score of 5) in areas of current high development pressure. This is represented using the recent percent population change estimates (2010 to 2012) for the county in which the farm resides (U.S. Census Bureau data). Farms located in counties in the 90th percentile (≥ 2.8% population increase, conterminous U.S. counties) will be designated as having land covers exposed to "high- development pressure", and the eco-weights of the land covers will be increased by 0.5. The result is that land covers on a farm experiencing a high rate of surrounding development pressure are valued slightly higher in order to provide an incentive to preserve the remaining amount of the land cover. Assignment of this modifying factor can be applied in the background of the HPI tool based on the county designation of the farm.

3.4 Development of the HPI parameters for Eco-quality scoring

3.4.1 Parameter definition

The HPI tool permits the user to enter basic information that describes the farm. The main input requirements in describing an individual farm are (1) the location of the farm and ownership status (own vs. rent) which may impact how the land is managed, (2) the acreages of cultivated and non-cultivated land cover/land use types, and (3) characterization of the quality of each of the land cover types. These inputs will be provided by the farm manager in the form of answers to questions defined in simple drop-down menu format. Specification of the location of the farm facilitates the use of county, state-specific, as well as ecoregion, data in implementing algorithms for evaluating habitat potential for individual land cover types.

In developing and refining the final HPI parameters, the emphasis was placed on:

1. Relevance to estimation of habitat potential

2. Minimizing the amount of information required from the user.

The algorithms underlying the calculation of the HPI are intended to be scientifically-based while requiring minimal input information demanded of the user. The algorithms are intended to infer the overall ecological quality and habitat potential of the specified land cover/land use types. Ecological quality is defined in terms of easily obtained information that describes ecosystem structure. The direct measures of contributions of ecosystem function to land quality and habitat potential are more difficult and costly to obtain. Therefore, the algorithms were developed to reflect the quality of ecosystem function based on information describing ecosystem structure (for example, the spatial configuration of a forest) and management actions provided by the user in the form of answers to the farm-scale survey questions.

The framework used to develop the HPI algorithms is similar to the approach used by various federal agencies (e.g., USACE, FWS) in characterizing habitat suitability for individual species of interest and selected ecological communities (e.g.,, wetlands). In this approach, relationships are constructed for each factor identified as contributing to habitat suitability. Habitat suitability for each individual factor ranges from 0 to 1 (optimal habitat). An overall habitat suitability index (HSI) is then estimated using a weighted average of the component habitat factor values. The resulting HSI similarly ranges from 0 to 1 with the same interpretation concerning overall habitat suitability. The HSI quality metric is then multiplied by the number of applicable acres to generate habitat suitability units (HSUs). The numbers of associated HSUs are used by the agencies to evaluate alternative habitat management and restoration alternatives (e.g., USACE planning process). Correspondingly, the HPI values are estimated as the weighted average of ecological quality factors (parameters) derived from information on structure, function, and management for each land cover/land use type at the farm scale (,e.g., Van Horne et al. 1991). Based on user inputs, each parameter is scored from 0 (i.e., no habitat potential) to 1 (maximum habitat potential). The parameter scores are calculated separately and then averaged across all attributes for the cover type and multiplied by 10 to derive an overall eco-quality score (0-10) for the particular land cover type. This approach offers several advantages:

1. The quality value (0-1) for each separate factor can be defined by various quantitative functional forms, categorical relationships, or semi-qualitative scoring;

2. Qualitatively very different kinds of factors (i.e., structural, functional, management related) can be readily combined in the calculation of the overall farm-scale HPI;

3. Quality factors can be easily added or removed in the overall quality evaluation of any land cover/land use type; and

4. Quality functions for individual factors can be readily modified and refined as new data or information become available (i.e., the HPI tool is designed to evolve over time).

3.4.2 HPI eco-quality algorithms

Apart from acreage, many of the farm-scale input descriptors (i.e., survey questions) have been defined as simple check-box "Yes/No" type of questions. This flexibility permits application of the HPI methodology across various levels of rigor and detail concerning the farm-scale description. This approach also avoids detailed (and expensive) quantitative measures of inputs such as soil chemistry, application rates of fertilizers and pesticides, and surface runoff, while still permitting their inclusion in estimating habitat potential based on management practices identified. Many of the HPI parameter algorithms are based on threshold values pulled from the literature; for example many of the surface water parameters are based on habitat classifications from the U.S. EPA Rapid Bioassessment Protocol (Barbour et al. 1999). The algorithms and their corresponding parameters for each attribute were developed using values relevant across a wide geographic scale wherever possible, however in some cases regional variability was used to customize parameter scoring. For example, scoring for the use of tile drainage may be dependent upon regional/local soil drainage characteristics, while scoring for the use of irrigation may be dependent upon water scarcity in the watershed in which the farm is located (using the "Water Supply Stress Index": USDA, http://www.wassiweb.sgcp.ncsu.edu/). Further detail on this scoring customization is provided in Appendix C.

3.4.3 HPI parameter types

HPI parameters can be classified as structural/functional or management-based parameters. Structural/functional parameters of the HPI include the physical characteristics and the spatial aspects (e.g., acreage, patch configuration, etc.) of a land cover type (Bonan et al. 2002). Phase I of the HPI tool development included a large number of structural and functional parameters for various land cover types, for example % canopy cover, as well as a proposed wildlife assessment parameter (relative measure of abundance of fish, birds, mammals). However, it was determined by the technical subcommittee that the level of effort required of growers to input detailed information for structural and functional attributes would be too burdensome, and that the structural/functional parameters required streamlining and simplification down to inclusion of only the most critical factors, with an emphasis on more simplified (e.g., Yes/No) input requirements. Additionally, it is recognized that many structural and functional attributes are not easily within a grower's control; therefore the Phase II HPI parameters and associated scoring reflect a skew towards management-oriented components.

Human activities at the farm scale that influence the habitat potential of the agricultural and other land cover/use types comprise the land management options. Conventional and best management practices (contributing to the diversification of the cropping system) from a conservation standpoint are offered as options to provide growers the capability to assess the habitat potential of current management practices and to provide learning opportunities for growers to investigate the extent to which the adoption of differing management strategies is estimated to positively or negatively influence habitat potential for the farm. It is recognized that the cost-benefit of a land management change as well as implications to productivity are key to the grower's decision making process. Management parameters selected for inclusion in the HPI parameters were those identified by the diverse stakeholders in the technical subcommittee to be most critical for supporting biodiversity.

3.4.4 Individual HPI parameters

In Phase I, 65 preliminary parameters (survey questions) were identified for the HPI across all land cover types, ranging from characteristics of land cover composition and land use change, structural and functional attributes of land cover, as well as associated management strategies. In Phase II, the list of parameters was refined with guidance from the technical subcommittee down to 29 parameters. The actual number of questions a grower will be prompted to provide input for is further limited by the specific land cover(s) present on their farm (i.e., most growers will not need to answer all 29 questions). Additionally, wherever possible, input from existing Field to Market metric tools will be imported to the HPI to automatically populate the parameter inputs.

The individual Phase II HPI parameters are summarized below in **Table 3** and detailed in Appendix C. Parameters which can likely utilize input from existing Field to Market metric tools are identified.

3.4.5 Differential weighting of HPI parameters

Differential weighting is applied in the eco-quality scoring of HPI parameters. For all land cover types, HPI parameters relating to direct management activities are assigned twice the weight of structural and functional HPI parameters to give greater weight to factors more directly within control of a grower. Parameters may additionally be weighted on a per-land cover type basis. For cultivated lands, the contribution of specific agricultural management practices to the HPI score for cultivated areas is differentially weighted using the cumulative for the practice

Table 3. Individual HPI parameters by land cover category. Management parameters are assigned double the weight of structural/functional parameters in the computation of the eco-quality score (see Eq. 1). Additional parameter weights are applied for cultivated lands using Environmental Benefits Scores (EBS) from NRCS conservation practice scoring, and reducing the influence of parameters related to riparian zone condition for ponds/lakes. Ability to import some/all parameter input from existing Field to Market metric tools is also denoted.

Parameter Category	Parameter ID	Parameter Name	Parameter type	Additional parameter weight (if applicable)	Import some/all input from existing FtM tool
All land covers	HP-0	Farm location and ownership	(Base input)		✓
	HPI-1	Current land cover (acreage)	(Base input)		✓
	HPI-2	Recent land cover change	Structural/functional		
Cultivated Land	HPI-3	Residue cover	Management	35	✓
	HPI-4	Crop rotation	Management	31	✓
	HPI-5	Cover crop	Management	42	✓
	HPI-6	Nutrient management	Management	19	
	HPI-7	Pest management	Management	31	✓
	HPI-8	Water conservation	Management	44	✓
	HPI-9	Drainage water management	Management	26	✓
	HPI-10	Wildlife enhancements	Management	87; 174 for seasonally flooded rice	
Edge features/ Riparian Buffer	HPI-11	Native vegetation (edge features/riparian buffer)	Structural/functional		
	HPI-12	Habitat management (edge features/riparian buffer)	Management		
Forest	HPI-13	Forest arrangement/fragmentation	Structural/functional		
	HPI-14	Habitat management (forest)	Management		
Grassland/Savanna	HPI-15	Grassland/savanna arrangement/fragmentation	Structural/functional		
	HPI-16	Grazing intensity	Management		

Parameter Category	Parameter ID	Parameter Name	Parameter type	Additional parameter weight (if applicable)	Import some/all input from existing FtM tool
	HPI-17	Habitat management (grassland/savanna)	Management		
Wetlands	HPI-18	Water regime	Structural/functional		
	HPI-19	Water level management	Management		
	HPI-20	Habitat management (wetlands)	Management		
Surface waters	HPI-21	Riparian buffer	Structural/functional	½ for ponds/lakes	
	HPI-22	Vegetative cover, riparian zone	Structural/functional	½ for ponds/lakes	
	HPI-23	Riparian zone management	Management	½ for ponds/lakes	
	HPI-24	Bank stability	Structural/functional		
	HPI-25	Channel modifications (streams and rivers only)	Structural/functional		
	HPI-26	In-stream disturbance (streams and rivers only)	Management		
	HPI-27	Primary use of pond/lake (ponds and lakes only)	Management		
	HPI-28	Depth of pond/lake (ponds and lakes only)	Structural/functional		
	HPI-29	Management of pond/lake (ponds and lakes only)	Management		

defined by NRCS, in order to align quantitative scoring of the HPI approach with established numeric rankings of management practices (see Appendix C for examples). The integration of established EBS values enhances the HPI scoring for management practices beyond simple binary "Yes/No" outputs based on adoption of BMP's and reinforces the multiple benefits of diverse cropping systems for production areas. Parameters regarding the condition of the riparian buffer zone were assigned half the weight for ponds and lakes compared with streams and rivers as the technical subcommittee considered these parameters should be more influential for streams and rivers.

For a given land cover type, the ecological quality value (0-10) is computed as:

$$\text{Ecological quality value} = 10 * \left(\left(\left(\frac{\sum(MCPI\ farm * W)}{\sum(MCPI\ total\ possible * W)} * 2\right) + \frac{\sum(SCPI\ farm * W)}{\sum(SCPI\ total\ possible * W)}\right)/3\right)$$

MCPI= individual management parameter scores, value 0 - 1
SCPI = individual structural/functional parameter scores, value 0 - 1
W= Additional parameter weight (if applicable, such as EBS values; otherwise = 1)

An example calculation of the eco-quality score is provided in Appendix D.

3.5 Benchmarking resolution

While the HPI tool is designed to evaluate habitat potential based on a scale of lowest to highest benefit to ecological quality for a given farm, it is also useful to place this value in the context of the status of other farms. Benchmarking provides a means for comparison of farm-scale HPI results to a population of farms in a similar context (geographic or other) using existing data. However, availability of relevant data resources to use for benchmarking can limit how HPI parameters can be benchmarked. It was determined by the technical subcommittee in Phase II that while the ability to benchmark HPI results would be a useful component of the HPI tool in the future, it should not constrain the optimal development of the survey questions that comprise the eco-quality scoring. Therefore, benchmarking remains a future consideration for the HPI tool, but not a current component of the tool. While the use of non-geographic factors (for example, farm size) would provide an informative option for benchmarking, most existing data is not available in a raw (individual farm) form that would enable the summarization of data by non-geographic attributes. The compilation of input into the HPI tool through pilot projects with targeted groups of growers (regional, farm size, type, etc.) could enable this type of benchmarking in the future, however actual versus scenario/test user inputs would need to be

specified to attain reliable benchmarking data. This section discusses geographic-based approaches to benchmarking that may be also considered in the future.
The primary considerations for benchmarking feasibility for each geographic scale were:

1. Relevance of the scale for benchmarking
2. Data availability (scale, coverage, and access constraints)
3. Data processing requirements (compilation and geoprocessing)

A variety of geographic scales were considered based on their potential relevance for benchmarking of farm-scale HPI parameters (**Table 4**), ranging from broad-scale regions (U.S. Land Resources Region, USDA) to watersheds (USGS hydrologic unit codes). During the initial development of the farm-scale HPI parameters in Phase I, a wide range of geospatial and other data resources were reviewed to determine benchmarking options and the available resolution and processing requirements of benchmarking at various scales. Some data resources, while relevant to the purpose of the HPI tool were found to be currently unsuitable for benchmarking due to limitations imposed by the format of the data available. For example, the USDA Soil and Water Resources Conservation Act (RCA) data viewer provides state and regional summaries of participation in USDA conservation practices within USDA conservation programs based on official enrollment statistics in the USDA-NRCS National Conservation Planning Database (raw data not available to the public). However, these data (# acres and # enrollments) are summarized by fiscal year and conservation practice. This summarization results in overlapping data records (farms counted multiple times across years and across practices) that make it difficult for meaningful benchmarking values to be developed. Furthermore, while official enrollment in conservation programs provides one measure of incidence of farming practices, this statistic is limited to representing only instances where the conservation practice is conducted within an official program. This can underestimate the prevalence of a given farming practice when considering the wider population of farm operators. Farming practice data evaluated for potential benchmarking feasibility were mainly obtained from other USDA resources (e.g., USDA ARMS, USDA NASS Agricultural Census) which were not limited only to survey respondents participating in conservation programs.

Potential future benchmark resolution options (**Table 4**) were assigned a ranking by data availability and processing feasibility (time and effort required for compilation and geoprocessing). The highest availability of data was at the scale of state boundaries, as many data resources, particularly management practices, were summarized at the state-level. The state level also provides reasonable geoprocessing feasibility in both land area and number of runs required (i.e., 48 states). While some data was available at a county- level (U.S. Agricultural

Table 4. Benchmark options evaluated, ranked by data availability and data processing feasibility (scale 1-3). Recommended benchmark resolution options are highlighted.

Benchmark Resolution Option	Description	Data availability rank (1= highest availability)	Data processing feasibility rank (1= highest feasibility)
USDA Land Resources Regions	*"Homogeneous areas of land use, elevation, topography, climate, water resources, potential natural vegetation, and soils"* (USDA)	3	3
USDA Farm Resource Regions (Economic Research Service)	*" Regions defined by similar farming characteristics"* (USDA ERS)	3	3
Ecoregional Province (Bailey, USDA FWS)	*"Large areas of similar climate where ecosystems recur in predictable patterns"* (FWS)	2	2
State	U.S. state boundaries	1	1
County	U.S. county boundaries	2	3
Hydrologic Unit Code (USGS)	Watersheds or sub-watersheds	3	2/3

Census and some U.S. Forest Inventory data), in general there was little data specific to geographic scales smaller than state-level at the coverage and practical ease of acquisition/processing required to provide an adequate benchmarking option for the HPI tool. Little data was available at larger regional scales, with the exception of forestry data which had some data summarized across U.S. Forest Service regions. Larger geographic regions (Land Resource Regions and Farm Resource Regions) are likely limited in their relevance for benchmarking, and they also pose a challenge with requiring greater time and CPU usage for any geospatial processing. While the state-level was identified as a relevant and feasible benchmarking resolution, it is also useful to account for sub-regional differences in climate, soils, and vegetation types which are generally independent of state boundaries and are critical factors in variation in habitat potential across a state. For example, the state of Ohio has a significant east-west division in ecoregion (based upon historic glacial activity) and resulting major east-west differences in land cover and use (Ohio EPA). Farm operators in the heavily agricultural (and highly fragmented forest) western portion of the state have a significantly different set of background conditions area compared with those in the more densely forested

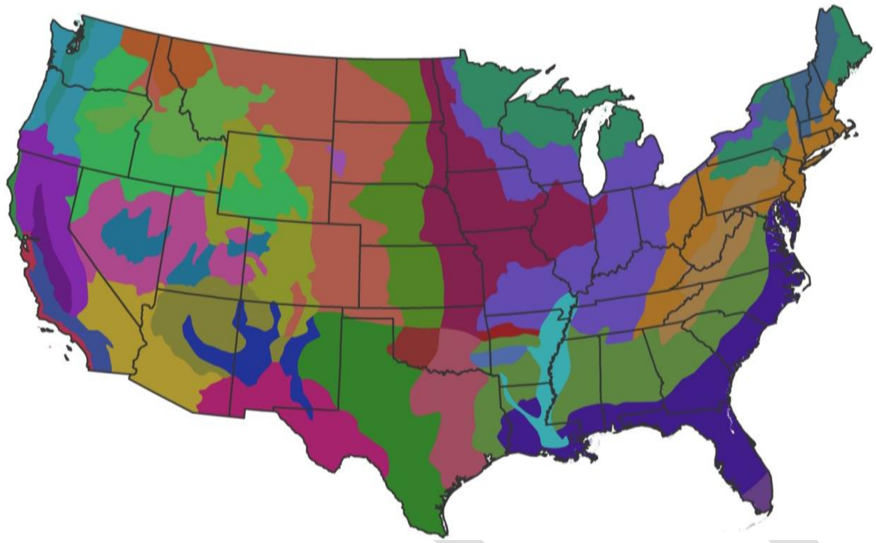

Figure 3. Recommended benchmarking resolution for potential future benchmarking of HPI: Ecoregional Provinces (FWS) and U.S. state boundaries (Feature intersection: N= 186 unique features).

eastern portion of the state. A benchmarking strategy that accounts for these differences would provide better point of reference for farm operators to see how their land cover and use compare with others in a similar geographic context. While the ecoregion-based ecological weighting factors (described previously) provide some standardization for this variability, it is limited to the importance attributed to particular types of land cover within each ecoregion and not the actual structural/functional attributes of the land cover determined by farm-scale survey responses or benchmarking data.

Our recommended resolution for potential future benchmarking for the HPI tool based on existing data resources is the state-ecoregion level, in addition to the state level (**Figure 3**). This entails the intersection of state boundaries with ecoregional province boundaries (Bailey, U.S. FWS), which yields 186 unique polygons. Data values specific to the state level (such as statistics on management practices) could remain static across ecoregion boundaries, but other data not limited by state boundaries (such as land cover) can be calculated at the state-ecoregion resolution to provide a more customized benchmarking point of reference for evaluating farm-scale HPI results. Geospatial data resources that were evaluated in Phase I that may be considered for *potential* future benchmarking are briefly listed at the end of the References section.

3.6 Farm-scale Habitat Potential

3.6.1 Summary options

The HPI components (acreage, eco-weighting, and eco-quality scores) can be summarized by various means based upon the desired assessment objective of Field to Market. Appendix D provides examples of the computation of an overall HPI score.

Example 1, Basic HPI score

A basic HPI value for a specific land cover type on a farm can be computed as:

*Land cover HPI = acreage * eco-weighting factor * eco-quality score*

Due to variability in land cover composition across different farms (often outside a grower's control) as well as acreage, use of the above HPI score is intended for use in benchmarking a grower to themselves, based on current and future land management. This number can be evaluated on a per-land cover basis as well as summed across land cover types to arrive at a score specific to the individual farm.

*Total HPI, Individual farm = ∑(acreage * eco-weighting factor * eco-quality score)*

Changes in the HPI score can be expressed as a percent increase (or decrease) in HPI based on different scenarios (user-input) affecting land cover structure, function and management. Additionally, this farm-level The variability in ecological weighting of land cover types allows a grower to identify land covers that may be prioritized for conservation and/or enhanced management in order to achieve the greatest improvements (% increase) in the HPI score. Individual farm-level scores would be optimally computed separately for cultivated and non-cultivated lands, as it is not the intention of the HPI tool to skew in a direction that requires converting croplands to non-productive land in order to receive a higher score.

Example 2, "% Realized HPI, Individual Farm"

In addition to a basic HPI score for an individual farm, the HPI score can also be expressed as a "% Realized" value based comparing the current HPI score of the farm to the total possible HPI score (eco-quality scores of 10 across all land cover types) for the current land cover configuration on the farm.

$$\% \text{ Realized } \mathit{HPI, Individual\ Farm} = \frac{\mathit{Total\ HPI\ Farm\ Score}}{\mathit{Total\ posslbe\ HPI\ Farm\ Score}}$$

(The above score would be computed separately for cultivated and non-cultivated land).

Example 3, "% Realized HPI, Specific Land cover"

Expression of acreage values as the proportion of the farm land is an alternative approach to computing the HPI score that would additionally enable more direct farm-to-farm comparison if desired in the future; however, it is recognized that growers should only be scored based on what is present on their farm (i.e., in their control). An additional HPI assessment that is suited to both comparison of an individual farm to itself and also other farms within a particular geographic area (e.g., state, subregion) is the expression of HPI in terms of "% Realized HPI". This measure puts habitat potential in terms of conservation performance relative to the maximum ecological quality (10) for each land cover present on a given farm. For a given land cover, this can be simply computed as:

$$\mathit{Land\ Cover\ \%\ Realized\ HPI} = \frac{\mathit{Land\ Cover\ Eco - quality\ score}}{10}$$

The "% Realized HPI" can also be averaged across all land cover types present on a farm to yield an average "% Realized HPI" value. Conversely, a % Realized HPI value can also be computed for individual HPI parameters for a specific land cover to provide a grower with more specific information on areas for potential improvement. The "% Realized HPI" is more relevant to the assessment of a farm's overall current conservation performance compared with the basic HPI score which is more suited to assessing potential or actual changes in habitat potential. As with the basic HPI score example, a grower can utilize the "% Realized HPI" to compare scenarios for their individual farm, and in addition due to the relative nature of this metric it can also be considered (if desired) for comparing individual farms to corresponding benchmark values at state or regional level.

3.6.2 Integration of farm productivity

An effort was also initiated in Phase I to explore ways to provide a linkage between habitat potential with agricultural productivity. As noted previously, the HPI approach was developed with the goal of balancing productivity with conservation and enhancement of existing habitat. One suggested option in Phase I was the addition of a "% soil yield potential realized" parameter, possibly represented by the soil conditioning index (SCI) already in the Fieldprint Calculator, as an individual parameter in the HPI score for cultivated lands to give growers additional credit for cultivating soils with high yield potential. Another option suggested in Phase I was the expression of productivity in terms of "habitat acres saved" based on the decrease in conversion of natural ecosystems to cultivated land (concept of indirect land use change) as a result of increased productivity (yield) on existing cropland compared to a baseline such as the state average productivity. .During the workshop in Phase II, however, it was determined by the technical subcommittee that these concepts are already accounted for by the existing metrics in the Fieldprint Calculator (Soil Conditioning Index and Land Use Efficiency Index), and that their inclusion in the HPI metric would result in direct "double-counting" of these concepts. The technical committee recommended that in contrast to the inclusion of productivity as a quantitative component of the HPI, that the recognition of the need for a balance between productivity and biodiversity would be communicated in the way the HPI score is computed and displayed. For example, as discussed previously, the separation of cultivated and non-cultivated land in the computation of an aggregate HPI score emphasizes the optimization of existing farm status, as opposed to encouragement of conversion of existing cultivated land to its "pre-cultivated" status. The emphasis on management practices across all land cover types (but particularly for cultivated land) provides direct opportunities for growers to positively influence biodiversity on their farm.

4.0 HPI spreadsheet tool

A macro-enabled Excel "mock-up" spreadsheet version of the HPI tool was developed in Phase I to provide a general understanding of the functionality and outputs of the application for Field to Market members. A Phase II HPI functional spreadsheet tool will be developed for beta-testing of the revised and updated algorithms and approach resulting from Phase II. The goal is to develop a HPI tool that could ultimately be integrated into a web-based application that can import relevant input from the current existing Field to Market metric tools.

The Phase II HPI spreadsheet tool will be completed upon final approval of the HPI parameters and methodology by the Field to Market Biodiversity Subgroup.

5.0 Conclusions

The primary objective for the Habitat Potential Index (HPI) metric development is to enhance the ability of growers to evaluate and communicate their land quality status as well as to understand opportunities for improvement without compromising productivity. Through the integration of existing strategies, resources and information from the literature, the HPI approach was developed to provide a scientifically-based proxy for biodiversity that is also driven by a focus on farm-scale information generally intuitive to a grower. Phase I investigated and developed a preliminary framework for estimating a farm-scale (HPI) for Biodiversity for eventual application as Field to Market metric. Phase II involved refinement of the HPI approach in close collaboration with experts in Field to Market to develop further consensus and streamline the HPI input, including integration (where possible) with existing Field to Market applications. Feedback from the Field to Market Biodiversity Subgroup and technical subcommittee members provided invaluable guidance for the development of the approach. Prior to the process of web integration of the final HPI tool, the prototype spreadsheet tool that will result from Phase II will be subject to a beta-testing “Phase III” for selected Field to Market members involving the implementation of a number test scenarios for optimal tool calibration.

Upon finalization of the HPI parameters and approach in Phase II, other considerations identified by the technical subcommittee regarding the web application of the tool include:

- Balancing the particularities of the HPI with the need for consistency in terms of scoring and displaying information, across all of the metrics included in the calculator.
- Data entry should be made as simple as possible for the user, by pre-populating land cover data from existing calculator input or providing sample data, whenever possible.
- The educational value of the scoring would be enhanced by visually presenting the information in a way that clarifies the benefits of different land cover types and management practices – for instance, a “slider” tool that shows how the application of different practices would impact a user’s score, or a “spidergram” that illustrates the relative values associated with land cover types.
- An assessment should be conducted to determine how many additional cultivated land-related questions (and, possibly, those related to edge features) would be required at the start-up page of the calculator in order to provide a field-level HPI score.
- Cultivated land questions should be incorporated into the start-up page of the Fieldprint calculator, so that, when users receive their Fieldprint score, they also receive an initial

field-level HPI score. After receiving this initial field-level score, users would be informed that if they have non-cultivated lands, they have additional options for increasing biodiversity. Users should then be invited to enter additional information for their other fields and land cover types in order to receive a farm-scale HPI score.

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Selected geospatial Data Resources that could be considered for future benchmarking:

- USDA NASS Cropland Data Layer (2008)
- NLCD 2006 Land Cover Change dataset
- USGS GAP Program data (Protected Areas, National Land Cover, and ancillary data)
- USDA Environmental Research Services (ERS) Agricultural Resource Management Survey (ARMS)
- USDA/NASS Quick Stats (Survey and Census data)
- USDA Agricultural Census 2007 (state and county profiles)
- US Forest Service Forest Inventory and Analysis data
- USDA National Resources Inventory (2007)
- USDA National Resources Inventory Rangeland Assessment (2010)
- USDA Soil and Water Conservation Act RCA data
- USDA PLANTS database
- USDA NRCS Conservation Easement layer
- USDA FWS National Wetlands Inventory
- US EPA National Stream Assessment (2007)
- US EPA National Lake Assessment (2010)
- National Hydrography Dataset Plus (NHD Plus, Horizon Systems)
- USDA SURRGO Soils Data