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Interpreting landscape change: Measured biophysical change and surrounding social context

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Abstract

Although research assessing both biophysical landscape conditions and social perceptions provide critical data on change, these methods are seldom integrated. In this study, we examined landscape change in the Central Iowa region by pairing quantitative data on changes to natural areas, streams, and housing density over the past 60 years with a qualitative social assessment of current resident stakeholders' interpretations of these changes. We found participants intuitively curious about and interested in landscape change within their region, and their interpretations of change to be fairly complex. Perceptions of change generally included an evaluative assessment, which often served to place measures of landscape salient to residents within a dualistic framework. This perspective both colored the data regarding landscape change and directed them to focus on attributes of change that the quantitative assessment did not. Finally, participants sometimes varied in their ability to assess change among metrics. These findings suggest how data gathering activities might be better sequenced and how metrics might better constructed to improve the utility and robustness of both participatory and non-participatory landscape change assessments.

Keywords: Integrated research; GIS; Social assessment; Qualitative analysis; Participatory assessments

1. Introduction

> Clear Lake, in Clear Lake Township, will contain fertile fields and tassling corn, and waving grain will grow where once the people of this part of the country were accustomed to gathering and spend the day boating and fishing. The farmer, filled with the desire to cultivate more land to plant in new corn fields to add to his accumulations of wealth, has decreed that this once famous lake must be a thing of the past. And now the owners of the lake are busy getting a large tile from the middle of the lake bed to Squaw Creek and when that is done it will leave the lake bed high and dry and several acres of fine farm land will be secured by the holders of the lake bed .... This will destroy the famous landmark in this part of the country as it was formerly a famous resort for pleasure seekers .... The lake originally covered 200 acres and was very deep and clear. Twenty years ago or more it was quite a summer resort, a number of boats were placed on it, some containing sails .... It was also a haunt for local hunters and fishermen. During several years past however it has been filled with reeds and seldom visited by anyone except muskrat trappers (Stratford Courier (Iowa) Newspaper (Editor, 1907)).

Patterns in the rural landscape are often as much a product of human purpose as they are of ecological process. The vision of landscape change for Clear Lake described above was typical across rural areas of the American Midwest around the turn of the last century. Within the span of just a few decades, systematic drainage efforts transformed a biologically diverse complex of small lakes, wetlands, and wet prairies into some of the most productive cropland in the world (Prince, 1997). Viewed as progress by most people, the loss of ecological and social values to those who looked to places such as Clear Lake for their leisure and livelihood was justified by gains made in the growth and prosperity of society at large.

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The environmental consequences of the agricultural intensification that occurred eventually led to policy innovation. The 1985 Food Security Act tied continued receipt of crop subsidies to environmental performance and created the Conservation Reserve Program to take highly erodible land out of production. Succeeding farm bills have authorized a number of incentive programs dealing with water quality, water conservation, air quality, wildlife habitat, and other environmental concerns related to agriculture (Board on Agriculture, 1993).

The Central Iowa landscape, the location of our study area and of the now-defunct Clear Lake, has been so thoroughly modified by agriculture that even features such as perennial vegetation cover and stream courses that most think of as natural are in large part socially constructed. Yet despite their modifications, these features continue to provide important ecological values for wildlife habitat, flood control, and water quality, and social values for recreation, aesthetics, and maintaining a regional sense of place.

Planners and researchers have developed local and regional landscape assessments to understand the biophysical and social dynamics of change in order to guide this new growth. However, few such assessments have been grounded in the experiences and concerns of residents, raising important questions. For example, are the features and patterns of change used in local and regional assessments similar to those residents also employ, or do residents use different criteria? Can new knowledge about landscape perceptions, beliefs, and values be applied directly to planning for landscape change, or does it require interpretation? It is with these questions in mind that the present research, utilizing two different methodological perspectives, was undertaken.

Landscape change assessments utilizing systematic, deductive methods have become more widespread in recent decades. Typically, assessment methods focus on landcover and/or land use characteristics, which, depending on the scale of the assessment and time span of coverage, are studied using periodically collected databases such as the US Census and National Resources Inventory (e.g., Alig et al., 2004), satellite coverage (e.g., Wang and Moskovits, 2001), and maps and aerial photographs (e.g., Drzyzga and Brown, 2002). Geographic Information Systems (GIS) can efficiently measure various landcover and land use characteristics such as the size and shape of different land uses (Palmer, 2004), the density of housing development (Hammer et al., 2004), and the length of stream corridors (Lalibert et al., 2001). This technology and the sophisticated measures that have been developed for it enable researchers and planners to measure spatial and temporal changes in the landscape and produce maps to help visualize dimensions of change that might not otherwise be apparent.

But while such assessments provide planners with critical data on various physical and social changes visible on the landscape, important differences may exist between these measures and what is perceived and experienced by residents in the region. In a study of landscape change in Massachusetts, Palmer (2004) found that landscape metrics derived from maps of land use data in the mid 1970s and mid 1990s predicted about half the variance in residents' preferences for on-the-ground scenes of the same areas photographed during the same two time periods. As for the other half of the variance left unexplained, Palmer hypothesized that "the way that landscape planners, designers, and managers classify the landscape and its elements may not adequately represent the way residents think about it" (p. 216).

Qualitative studies scrutinize social phenomena in order to understand the meaning of the events for those involved in them. This understanding can provide another layer of understanding to the types of quantitative biophysical and social assessments mentioned above. Stewart et al. (2004) used a photo-elicitation technique to understand residents' perceptions of landscape change in a rural fringe area experiencing rapid development. They found that community values tied closely with the landscape features portrayed in participants' photographs and could form the basis of visions for landscape change within a planning process. Gobster and Westphal (2004) used focus groups and interviews to examine stakeholder perceptions of an urban river corridor. They found that local residents often had a low awareness of the extent of the river beyond their immediate neighborhood, tended to think about the land and waterscape in evaluative terms, and focused on visible features such as the clarity of the water.

Additional findings of landscape change research reinforce the need to adopt approaches integrating social and biophysical assessments. Van Eetvelde and Antrop (2004) concluded that measures from aerial photos and census data were insufficient in understanding landscape change, and suggested combining these measures with interview and oral history data. Other researchers have found that residents often perceive landscape change differently than professionals (Luz, 2000), and that environmental knowledge regarding landscape change is not often effectively communicated between residents and professionals (Luz, 2000; Heimlich and Anderson, 2001). Brandenburg and Carroll (1995) argue land management conflicts can occur when the process of public involvement overly simplifies resident values, and suggest that qualitative methods of social analysis can provide a richer understanding of these values.

These issues drive the present research, which focuses on an agriculturally dominated watershed in Central Iowa. The objectives of the research were to: (1) use GIS to map landscape changes over a 60-year period, employing metrics visually observable by residents for natural areas, stream channels, and human occupancy; (2) examine the social context surrounding these changes among various stakeholder groups; and (3) explore the interface between these two data sets to improve the utility and robustness of landscape change assessments.

2. Methods

2.1. Study area

Our study area was the Squaw Creek watershed, a 65,154 ha sub-basin of the South Skunk river in Central Iowa, U.S.A. (Fig. 1). The study area is located in the Des Moines Lobe ecoregion, a nearly level landscape dominated by Clarion–Nicollet–Webster soils that is one of the most recently glaciated in Iowa. The first Euro-American settlers in the 1850s discovered primarily wet and bluestem prairie, with "the natural

Fig. 1. The study area is located in the Des Moines Lobe ecoregion, a subregion of the Western Corn Belt Plains Ecoregion (Griffith et al., 1994).

drainage of the country very imperfect" (Payne, 1911, p. 20). By 1905, 89% of farmland in the area was classified as "improved" (Iowa Executive Council, 1905). Agriculture remains the principal land use today, aided by extensive surface and subsurface drainage networks. Only a small percentage of wetlands remain; larger potholes, such as Clear Lake, and smaller wet areas were drained by tiling, ditches, and stream channelization (Menzel, 1987).

The study area, comprised of portions of three counties, is predominantly rural and in private ownership. Agriculture is the principal land use, with 92% of study area counties devoted to agricultural production (U.S. Census of Agriculture, 1999). The study area includes the City of Ames, with a population of 50,731 that includes the land grant Iowa State University, and three rural communities with populations of 500–1000 each (U.S. Census of Population and Housing, 2000). Despite intense agricultural use, important natural area remnants exist and the watershed serves as a critical aquifer recharge zone for Ames and for rural residents in portions of nine counties.

2.2. Measuring landscape change

The initial study area was delineated using the 11-digit hydrologic watershed boundaries for the Squaw Creek watershed developed by the Iowa Department of Natural Resources. These boundaries were slightly expanded or reduced to the next road or land section boundary (not exceeding 1 km) as needed to obtain visually definable limits of study for resident participants.

We compiled hardcopy black and white panchromatic air photos of the study area for four photo dates: 1939 (1:20,000), 1958 (1:20,000), 1978 (1:40,000), and 1998 (1:40,000). Air photos were scanned, rectified with USGS 1994 digital orthophoto quarter quads, and cataloged into GIS datasets based on the photo date. We measured changes in the three landscape elements based on separate photo-interpretations of the air photos. We used only the center section of each photo to help minimize distortion in GIS measurement.

2.2.1. Natural area change

We classified all perennial vegetative landcover as "natural areas," excluding lawn in farmyards and road rights of way. We examined only the portion of the study area that remained undeveloped for the entire study period. Natural area cover patches were digitized as polygons using three categories representative of the region: grasslands, open woodland (10–25% tree cover), and closed canopy forests (>25% tree cover). We used a fourth category, other, for all unassigned area. Rural land areas not in natural area cover were assumed to be cultivated cropland. To help ensure reliable coding, a senior research assistant rechecked all data entries and assignments by those digitizing the maps and made corrections when needed.

2.2.2. Stream change

We measured channel thalweg length, sinuosity, and recorded stream order for Squaw Creek and all tributaries separately for each photo date. Stream thalweg was digitized as polyline data.

Stream segments were defined by an intersection with an entering tributary. Each stream segment was assigned a unique ID number (autoID) and its length and sinuosity measured. Segments were compared between photo dates using the autoID and changes recorded.

All autoID assignments were manually verified between photo dates for accuracy. While autoID assignment helped to produce reliable comparisons of stream metrics across photo dates, manual adjustments were often required. For example, where tributaries existed in 1939 but were not present in later years, the corresponding segments in later years were split and assigned multiple autoIDs so analysis would match the identical beginning and end point of each segment.

Sinuosity is defined as the thalweg length divided by the most direct distance between the beginning and end of a segment. While some changes in sinuosity result from direct human activity, such as channelization, sinuosity is also self-adjusting. Channels are expected to migrate or meander as they attempt to balance energy. Sinuosity values range from 1.0 (a straight line) to more than 2.0 (a sinuous channel twice as long as the direct distance it covers).

2.2.3. Housing density change

Data used for measuring changes in housing density was digitized in each photo date for the entire study area. Density was computed for the 1939 and 1998 datasets using a kernel smoothing (Berman and Diggle, 1989) function in the Splancs library (Rowlingson and Diggle, 2005) for R (R Development Core Team, 2005). We used a kernel bandwidth of 1000 m and computed housing density on a 200 × 200 point grid across the study area. A density surface was created in GIS for both datasets using Inverse Distance Weighting; housing density was measured in square meters. Groups were created for both datasets separating density range into six classes. We calculated areas for each density class to compare change between classes and between the two photo dates. These areas summarize the smoothed surface of housing density and indicate changes in spatial coverage of housing density over time. However, the housing density, unlike elevation, cannot be unambiguously defined at a single point, so the housing density surface does not reflect a 'real' surface.

2.2.4. Cultural and agro-social change

U.S. Census Bureau data were used to characterize changes in population and household size (U.S. Census Bureau, 1940–2000). Census of Agriculture data were used to characterize changes in land use, farm size, and landcover (U.S. Census Bureau, 1925–1999). Census data from both types were matched to photo dates as closely as possible to produce a broader description of activities in this region throughout the study period.

2.3. Social assessment of landscape change perceptions

In this part of the study we involved a broad range of watershed residents to understand: (1) how they construct and interpret change in natural areas, streams, and housing and development, and (2) their beliefs about the quality and/or condition of natural areas and streams and what this means to them. We drew a purposive sample of 58 participants from the study area. Participants represented four stakeholder groups: farmers, non-farm rural residents, urban residents, and city-county officials.

Location in the study area, length of experience in the region, and occupation were among the factors guiding participant selection within the four stakeholder groups. Farmers ($n = 16$) were chosen by USDA Natural Resources Conservation Service (NRCS) field office staff in each county. NRCS staff members have in-depth knowledge of and experience with local farmers, the conservation practices each uses, and farm policy generally. Zube et al. (1989) reported that participants who use public open spaces are better able to comment on their condition and character than non-users. This finding helped guide selection of participants for the two non-farm resident categories. County Conservation Directors provided a list of residents active or interested in the use of public natural areas. Half of the participants selected for the non-farm rural resident category ($n = 10$) and the urban resident category ($n = 15$) were from these lists; the remaining half were chosen randomly from a list of property owners in the study area. Finally, city-county officials ($n = 17$) were chosen to represent the land resource issues inherent in our study. This included elected boards of supervisors and county planning and zoning directors, conservation directors.

The assessment included semi-structured, one-on-one interviews and observation. Questions were initially directed at the two types of information sought. The open-ended nature of the interviews, however, allowed discussion of additional topics as the interviews occurred. None of the interviews exceeded 45 min in length, and all were conducted at a location chosen by the participant, usually their farm, home, or office. All assessment methodology followed IRB requirements for research with human subjects.

One interview distinguished itself from the others. It was with a married couple, both lifelong residents of the study area. Their individual perceptions and beliefs were singular and thus were coded as one participant. Because of their unique insights, we interviewed this couple a second time and used excerpts from the recorded transcript in this paper to introduce the results and situate data from the physical and social assessments within key thematic contexts.

We designed this qualitative part of the study to ensure trustworthiness, meaning that results are credible, transferable, and confirmable. The trustworthiness criterion was addressed with two accepted techniques: the use of two reviewers to analyze data, and member checking (Guba and Lincoln, 1998). Both social assessment researchers (principal investigator Wagner and senior research assistant Zahradnik) attended all assessment interviews and compiled a summary set of notes following each. Both researchers coded data separately using specific categories, expanding categories into broader themes. The researchers used member checking by allowing interested participants to review the analysis and provide feedback.

3. Results and discussion

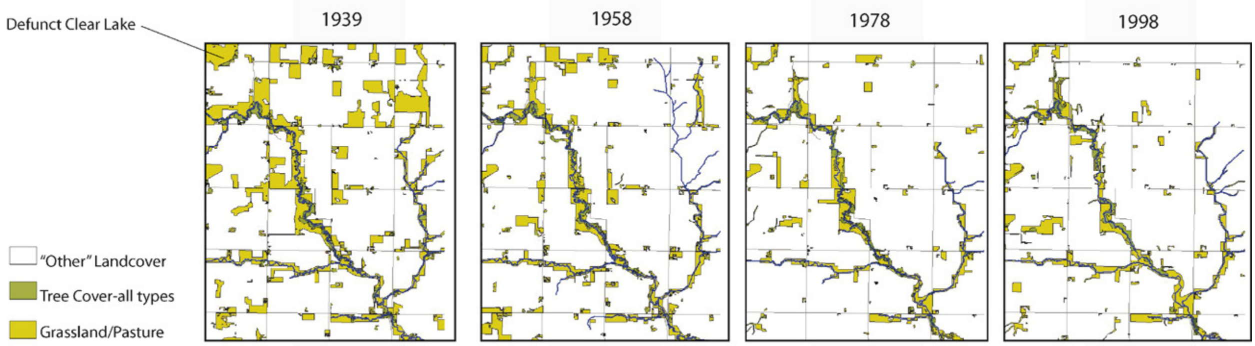
While agriculture dominated the regional landscape throughout the course of our 60-year study period, the average farm shifted from a diverse, family-operated system to a largely monoculture enterprise, increasing 167% in size. Both participant accounts and our measurements identified striking shifts in landcover, stream channels, and housing density accompanying this agricultural reorganization (Fig. 2).

3.1. Overture: "We haven't moved very far from where we were born"

Smiling, Carolyn relates "I was born right here in this [township] section. I've lived here for 73 years." Jim adds, "We haven't moved very far from where we were born. And now these [new neighbors] live all the way across the world from where they were born." Their lives together on this land provide a touchstone to the history of landscape change in our study area.

> J&C: We never farmed full time. When we got married in 1950 we got this place here so we had 160 acres—the most we ever did at one time . . .. When we were farming and first married we had some cattle, some chickens, and a few pigs running around there and now you either raise chickens, or you raise pigs, or you raise cattle and you raise it in a big way. The cattle would graze in the woods . . .. Every little field was fenced in.
>
> Little by little the small farmers couldn't make a go of it. You needed a certain number of acres to make a go of it. And if you had that certain number of acres you needed bigger equipment and you needed to pay for this bigger equipment, so let's get a little more land. And the little fellow, we couldn't afford the bigger equipment or we didn't want to buy up the extra land. I went to town in 1950 and I got a job. A guy came along and wanted to buy the farm anyhow so we sold him the farm.

Natural Area and Stream Change Data	1939	1958	1978	1998
Measured Natural Area Cover[1] (% of study area)	**17.9**	**11**	**9.4**	**9.8**
Land in Farms[3] (% of study area counties)	96.3	96.4	95	92.4
Number of Farms in Study Area[3]	7,233	5,695	4,020	2,599
Measured Stream Length Change[2] Added segments length / Removed segments length		**+44,844 m** / **-6851 m**	**16,958 m** / **-21,382 m**	**+15,730 m** / **-23,157 m**



Housing and Population Change	1939	1958	1978	1998
Rural Houses Measured[4] (% change from 1939)		**+3.6**	**+20.8**	**+28.9**
Rural Population[5] (% change from 1939)		-12.4	-33.2	-39.3
Person Per Household[3]	n/a[6]	3.01	3.03	2.48

1. Table 1
2. Table 3
3. Source: U.S. Census Bureau
4. Table 5
5. Source: U.S. Census Bureau & Table 5
6. Data not circulable

Fig. 2. Biophysical landscape change data summary, by photo date. Results from three measured change elements in this study shown in bold; all other sources of agro-social data shown as non-bold.

As former farmers, Jim and Carolyn Harris provide a unique kind of "insider" knowledge to help interpret the changes in agriculture they believe impacted change on the land, as well as empathy for decisions made by the agricultural community. They were able to articulate their beliefs and perceptions without the hesitation we perceived when interviewing active farmers. Their explanations seemed to communicate the emotional distance typically expected from outsiders, perhaps as a result of their non-agricultural income since 1950.

3.2. Natural areas: "It's not as good as it was—nature"

> J&C: Pretty soon [the farmer] has so many acres to farm . . . he had to go just to the farming part of it. And that's when he found out that fences kept him from getting two or three or four more rows of crop so then they started taking fences out. So what cattle are raised now are raised in a lot beside the barn. They don't let them go out in the timber . . .
> The quail were the first thing that went. Quail used to live in these fencerows and there's not very many around here anymore, not like they used to be. They used to be all over the place. Meadowlarks are gone. A lot of birds used the wooded area and the fence rows for habitat. When that went, they went with it.

The Harris' perceptions about the loss of natural areas frame the overall changes we measured. The total amount of natural areas measured declined 43% during the study period (Table 1). Additionally, we identified significant changes in the juxtaposition of natural areas between photo periods. Only 4% (3095 ha) of the study area was identified as continuously remaining in some form of natural area cover between 1939 and 1998.

Most participants concurred with these data and with Jim and Carolyn's beliefs about agriculture's impact on the loss of natural areas (Fig. 3). Looking across all stakeholder groups, 77% of changes in the landscape that resulted in negative impacts to wildlife or habitat were attributed to agricultural practices. These changes included cropping closer to streambanks, replacing natural areas with cropland, fencerow removals, and increased pesticide use. As one rural resident elaborated, "There are less natural areas. The timber is all along the creek in this area, but some farmers farm right up to the creek edge. I no longer see jackrabbits, quail, meadowlarks, and red-headed woodpeckers here. The farm fences have been taken out."

Breakdowns by group showed that 87% of city-county officials and rural residents felt that these negative changes to wildlife and habitat were due to agricultural practices. Farmers and urban residents attributed only 50 and 58% of this negative change, respectively, to agriculture.

Table 1
Natural area landcover measurements (ha), by photo date

Landcover type	Photo date			
	1939	1958	1978	1998
Grassland area				
Total measured in photo date	9105	5020	4046	4405
Area remaining from previous photo date		3296	2218	2217
Loss from previous photo date				
Converted to open woodland		239	159	145
Converted to closed canopy forest		152	195	165
Converted to other		4964	2374	1521
Gain from previous photo date				
Converted from open woodland		117	148	132
Converted from closed canopy forest		251	102	176
Converted from other		1356	1579	1880
Open woodland area				
Total measured in photo date	493	714	430	382
Area remaining from previous photo date		195	113	75
Loss from previous photo date				
Converted to grassland		117	148	132
Converted to closed canopy forest		106	346	163
Converted to other		154	93	60
Gain from previous photo date				
Converted from grassland		239	159	145
Converted from closed canopy forest		114	102	114
Converted from other		166	25	48
Closed canopy forest area				
Total measured in photo date	978	804	1181	1251
Area remaining from previous photo date		481	507	789
Loss from previous photo date				
Converted to grassland		149	98	176
Converted to open woodland		222	95	114
Converted to other		102	74	87
Gain from previous photo date				
Converted from grassland		152	178	165
Converted from open woodland		106	280	163
Converted from other		64	279	133
Total natural area cover	10,576	6537	5659	6038

"Other" category includes unassigned landcover (primarily cultivated cropland) as well as planted tree cover and open water (less than 1% of study area).

3.2.1. *"The pastures have been plowed"*

The historical diversity of farming practices in the study area mentioned by participants was perhaps best reflected in the proportion of grasslands, which in 1939 accounted for a substantial 14% of land area. Losses of grassland were the highest of any natural area cover type measured in the study period. Loss of grassland/pasture area was also the natural area change most frequently mentioned by participants, with 1/3 of our sample referring to changes in the overall quantity present or the size of individual parcels. We measured a 52% loss in grassland cover between 1939 and 1998, with a slight increase measured between 1978 and 1998. The number of grassland patches consistently decreased until 1998, while mean size remained within 2.12 ha, suggesting removals of entire patches rather than reductions in individual parcel size (Table 2).

Participants attributed recent increases in grassland area to changes in both policy and agricultural practices. Seventy-five percent of farmer participants described the amount of upland pasture and grassed stream buffers as increasing, primarily due to the Conservation and Wetland Reserve programs and other federal and state-funded agricultural conservation programs. Others noted that recent, small parcels of grassland have emerged in field corners because they are unreachable with the larger equipment currently used.

3.2.2. *"[To me] ungrazed wooded areas are a waste"*

> J&C: "Those trees along the creek have probably been there forever. Since the [American] Indians were here I'm sure. When farming got bigger, the wooded areas and the pasture areas just laid idle. The woods look a lot different when they're not grazed. When the cattle grazed the land they kept all [the understory] down and now there's nothing to eat it. There's a lot more growth of the little trees. It's deer country and mushroom country now . . . When we first moved here, [whenever we] saw a deer the whole family would run out there and say, 'there's a deer, look at that!' And now we've got them running all around the house.

Changes in the juxtaposition of tree cover types between photo periods and participants' perceptions of these changes were more extreme than for any other cover measured. Less than 2% (8 ha) of open woodland patches present in 1939 were continually present in each subsequent photo date. The patch described by the Harrises above was classified as open woodland cover in 1939 and, along with 46% of all losses of open woodland cover during the study period, was classified as closed canopy forest in later photo dates. Like Jim and Carolyn, other participants related that a reduction in grazing livestock resulted in trees "coming into natural areas," suggesting woody succession. Four rural resident participants perceived new patches of woody vegetation – described as "brush" and "trees" – as a positive change for wildlife. Four other participants perceived this change as negative for wildlife because, as one stated, "[the closed canopy areas] are too thick for wildlife to get through—the understory needs to be cleared so wildlife can use it."

Closed canopy forest cover was measured as the most stable in terms of gains and losses to total area of all natural area cover types measured. It also saw the largest increase in area during the study period. A range of 49–67% of closed canopy landcover area measured in each photo date was continually present in the subsequent photo date. A loss in overall area was measured between 1939 and 1958, with nearly equal portions converted to grassland, open woodland, and other landcover. Beginning in 1978, however, overall gains to closed canopy forest were larger than losses. The number of closed canopy forest patches decreased in each subsequent photo period, particularly between 1939 and 1978, while mean size increased 300% (Table 2). One explanation for this duality might be that some patches were converted to other uses while others expanded due to benign neglect or purposeful management. But if this is the case, the reason for these shifts may be more complex than simply that of agricultural production ver-

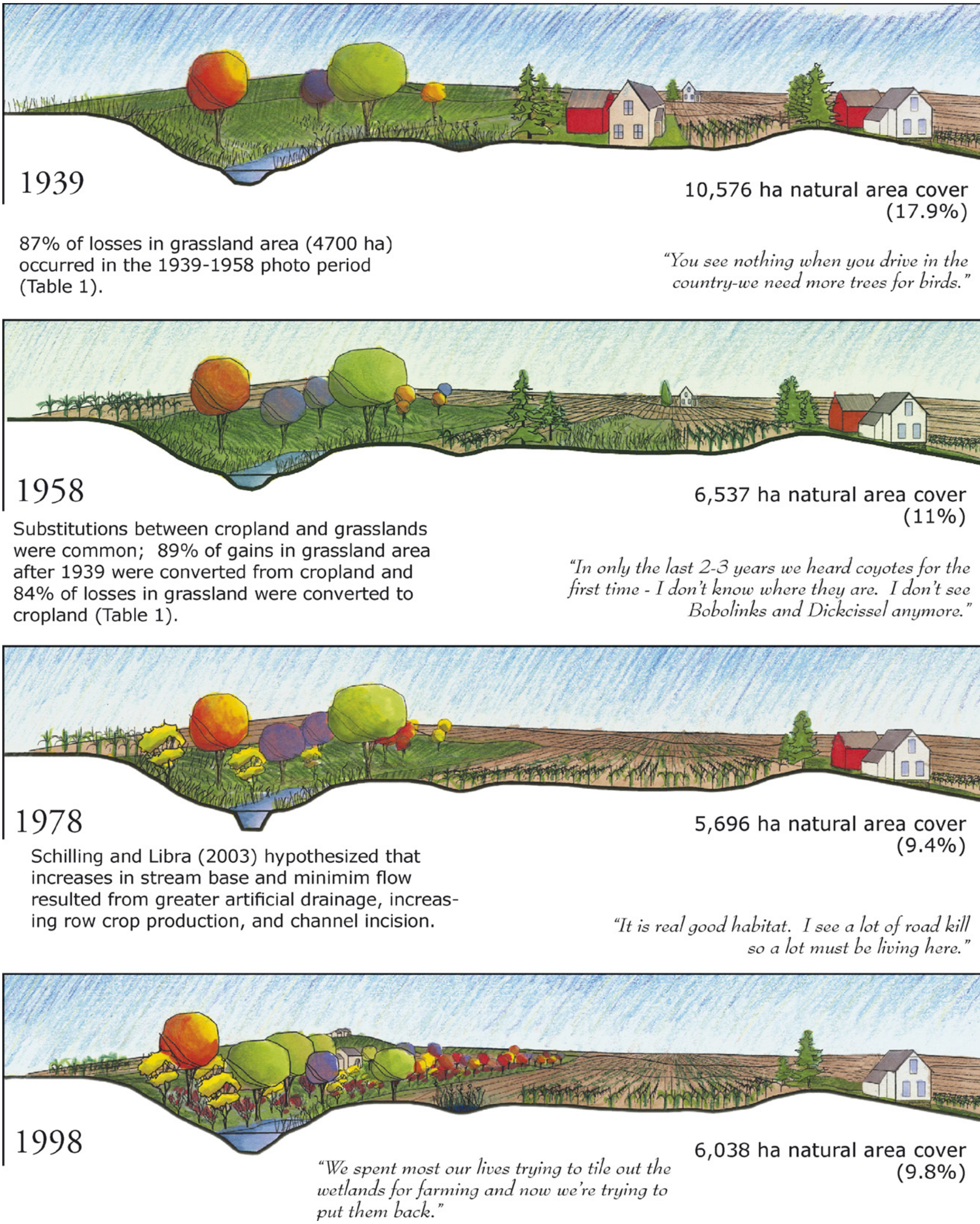


Fig. 3. Natural area change summary. Biophysical findings are integrated with resident quotations (italics) to characterize measured landscape change and perceptions of existing conditions.

sus woodland conservation. Several participants mentioned that some "tree clearing" had occurred for prairie restoration, and two felt this activity would reduce the amount of wildlife present.

Other research has identified similar trends in landcover change in the Midwest and Great Plains regions of the U.S.A. Mohlis (1974) and Medley et al. (1995) identified increased amounts of cropland and forest areas as well as declines in

Table 2
Patch quantity and mean area (ha) (in parentheses) for each natural area landcover type, by photo date

Landcover type	Photo date			
	1939	1958	1978	1998
Grassland	1314 (6.67)	1103 (4.55)	654 (6.19)	741 (5.94)
Open woodland	631 (0.78)	638 (1.10)	228 (1.89)	228 (1.68)
Closed canopy forest	820 (1.19)	406 (1.98)	240 (4.93)	262 (4.77)

pasture. Mohlis studied change between 1939 and 1972 in 27 counties, the majority of which also lie in the Des Moines Lobe ecoregion of Iowa, while Medley et al. studied between 1934 and 1984 in southwestern Ohio. Our results found a 52% loss of grassland area, compared with 63% from both Mohlis and Medley et al. Medley et al. also identified a decrease in open woodland area after 1956. Similar to both studies, we measured an increase in closed canopy forest area.

3.3. Streams: "There is not a lot of change in streams"

Although overall stream channel length in the basin fluctuated only 11% (37 km) during the entire study period, from a low of 350,507 m (1939) to a high of 387,975 m (1958), we measured larger changes between photo periods in the length of new channel construction and removal (Table 3). Participants, on the other hand, struggled to respond to the questions of stream channel change, focusing many of their comments on stream water or impacts they perceived resulting from change, rather than the channel itself (Fig. 4). Forty percent of participants felt unable to determine if streams had changed, compared with the same response for natural areas (14%) and housing (12%). Of the remainder, 36% observed changes they related to deteriorating conditions, 14% perceived streams unchanged, and 10% observed changes that improve overall conditions.

We measured three types of stream length changes and organized stream segment data based on them for each photo date: (1) overall stream channel length; (2) length of segments removed from previous photo date; and (3) length of added segments from previous photo date. In contrast, participants used three metrics in discussing stream changes and conditions: (1) channel and drainage modifications; (2) water levels; and (3) water quality. Using these metrics, participants made 38 comments regarding perceived changes. Eighty-seven percent of these comments described a change they related to a decline in condition.

Most participants (93%) associated changes in streams with human activity, both urban and agricultural. However, a few participants from three of the four groups felt that stream changes were due wholly to the amount of rain occurring in the watershed. One city-county participant explained their source of information, ". . . Our consulting engineer told us that stream changes and flooding aren't due to development—it's the weather and this is out of our control."

3.3.1. "The stream beds are more deeply incised"

> J&C: The creek [alignment] has stayed pretty much the same. I mean, there's some shifts in it. If you have a flood, and maybe that creek is running bank full, and then maybe a tree falls into it. Why then that will divert the water going a different way. Because when there's a bend in it and there's a lot of water, then it just keeps eating and eating [the streambank].

Only five participants, less than 10% of the sample, described three types of channel modifications: channel straightening (two city-county participants); channel conversions to culverts (farmer participant); and field tiling systems (rural resident and city-county participant). Additional physical changes reported included higher streambanks, wider channels, and lateral channel movement. This was a small representation considering the radical nature of channel changes we measured.

We identified patterns of both new channel construction and removal of entire channel segments. All segment removals on the 1939 channel (18,531 m) occurred exclusively on first and second order streams and were distributed among each photo period (Table 3). After 1939, we measured 77,532 m of new channel length constructed, with 58% in place by 1958. Fifty-seven percent of this added length was removed by 1998, suggesting conversion to underground drainage tiles. When these changes are placed in a temporal context, interesting patterns emerge.

Photo periods, relative to stream changes, can be described generally as either periods of channel extension or channel shortening. Zucker and Brown (1998) identified the 1940–1960 period as one of major agricultural drainage in the United States. The 1939–1958 photo period in our study area consisted largely of channel extension, with a net gain of 37,468 m (11%). Total channel length decreased by 7% (26,120 m) between 1958 and 1978. The 1978–1998 photo period again saw a net gain of 21,477 m (6%) in overall length. The photo periods we identify as periods of channel extension correlate with Urban and Rhoads' (2003) research on channel thalweg changes between

Table 3
Stream channel length (m) and mean sinuosity change summary, by photo date[a]

Measure	Photo date			
	1939	1958	1978	1998
Total channel length and sinuosity measured in photo date	[350,507; 1.41]	[333,465; 1.4] 387,975; 1.22	[315,760; 1.35] 361,855; 1.21	[334,958; 1.41] 383,332; 1.24
Length of segments removed from previous photo date		[−6851]	[−5051] −21,382	[−6629] −23,157
Length of segments added from previous photo date		44,844; 1.13	16,958; 1.12	15,730; 1.23

[a] Non-bracketed numbers reflect totals for all segments identified in the photo date; bracketed numbers indicate measurements for channel segments identified in 1939.

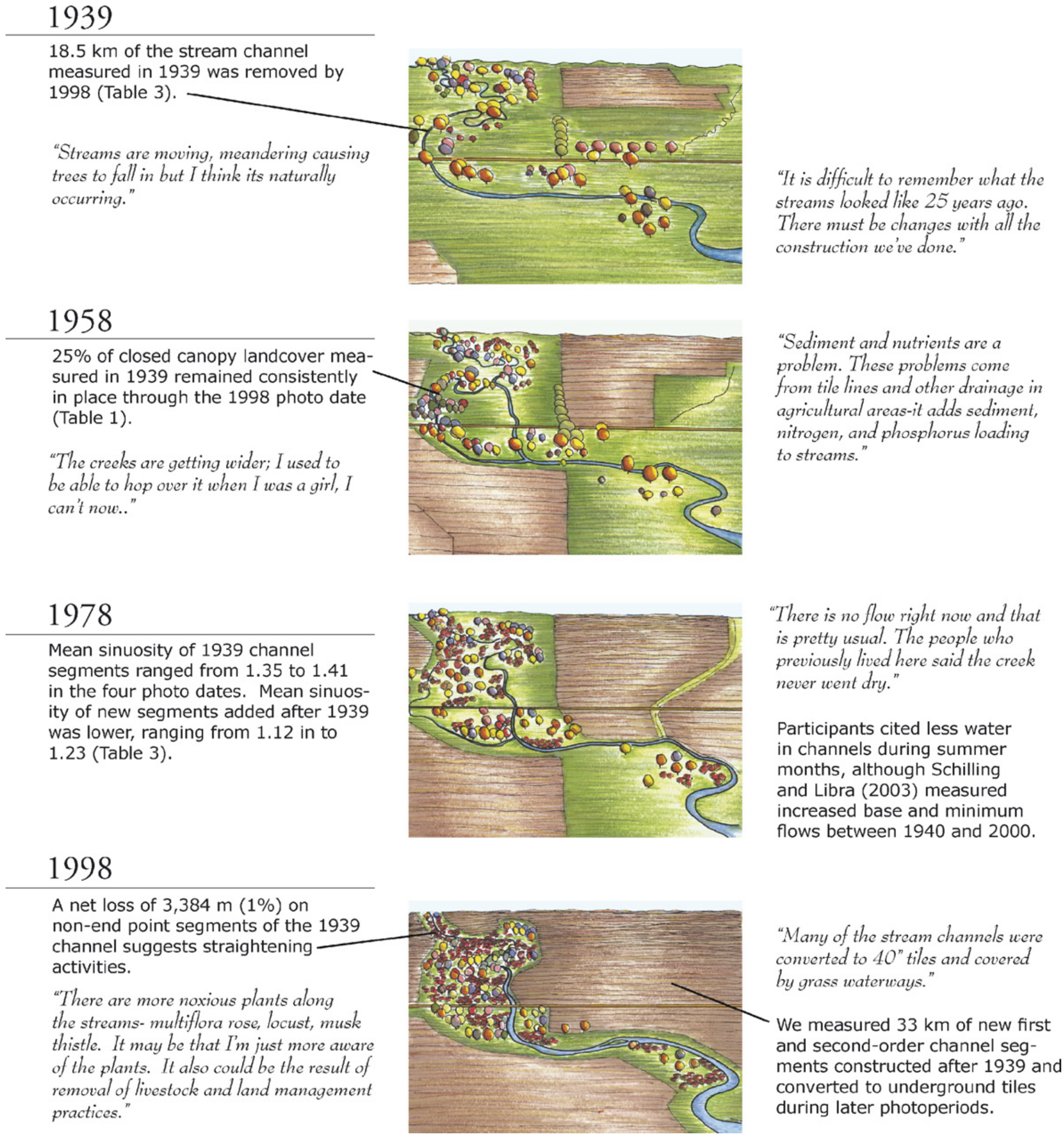


Fig. 4. Stream change summary. Sketches illustrate typical conditions and are accompanied by resident quotations (italicized) and our change measurements. Metrics used by residents to describe stream change often differed from those used by traditional landscape change research.

1936 and 1993 in a geomorphically similar low-relief watershed in Illinois, U.S.A. Although they do not report channel extensions or removals of entire segments, they reported significant periods of channel straightening between 1936 and 1954.

3.3.2. *"Streams are moving, meandering, causing trees to fall in"*

Total mean sinuosity for all channel segments in the study area decreased continually from 1.41 in 1939 to 1.25 in 1998, suggesting long-term, incremental efforts to straighten channels. While these differences are seemingly small, they are significant enough to alter stream type classification. Rosgen (1996) uses sinuosity as one criterion for determining stream type, although it carries the least weight of the Level II inventory criteria. In this index, low sinuosity in an A type stream is less than 1.2; moderate sinuosity is greater than 1.2 for B, G, F types; and very high sinuosity is greater than 1.5 in an E type stream. Using this index, the sinuosity rating for the 1939 channel was moderate while the 1998 channel was classified as a low sinuosity stream.

3.3.3. *"There doesn't seem to be near the water in Squaw Creek now"*

> J&C: There was always water in the creek running all through the summer. And now you look down there in the middle of summer and there are weeds growing up in the middle of the creek. And I don't know exactly why that is. It used to always flood in the spring and in the fall. If it didn't flood in March, it would in August. That was the rule of the land at one time.

Participants, including the Harrises, had the greatest consensus on stream change relating to water levels. Twenty-six percent of participants, proportionately divided between the four groups, reported a lack of water during the summer and winter months and greater level fluctuations after rain. One city-county participant stated, “The variation in flow seems to have changed; now it has very noticeable fluctuations.” A farmer relates his experience growing up in the study area, “The tributaries have less water. I used to have to take a pony across the creek when I was a child but now I can walk across it. I used to catch catfish in the creek but I’m not sure if this is possible now.”

3.3.4. *“It’s okay for the wildlife to drink”*

> J&C: I don’t know how we lived in those days. The best water we had to drink then was coming out of a tile along the creek. Nice, clean water. You didn’t think about it. We never thought about it being a problem for the kids to go wading. Now I wouldn’t let the grandkids go down and wade in the creek for anything, with all the runoff from all the chemicals from the farmers. If you drank that water now you’d probably die.

There were considerable differences in perceptions of water quality among participants in different parts of the study area. Human health relative to contact with stream water is an example. One rural resident reported contracting Hepatitis A after wading. A farmer from the northern part of the study area insisted that the stream water was safe for people, stating “My kids swim in it and it doesn’t affect them.”

The issue of livestock in the watershed also raised differing perceptions relative to water quality. Four participants felt that less cattle grazing has enhanced water quality, as fewer livestock are wading in streams. Another participant, however, reported that streambanks were eroding because of livestock. The attribution of fish kills to manure spills from animal confinement operations was also disputed by three participants. One urban participant felt that fish kills were a common occurrence. Two farmer participants believed that they didn’t occur.

Differing expectations appeared to affect how participants perceived change in stream condition. While many differences in perception among participants were explainable by their geographical frame of reference, others emerged despite a seemingly identical context. Wildlife use of streams was one of these. Two farmers cited the presence of deer using streams as an indicator that stream conditions remained the same. Wildlife use served as an indicator for a decline in condition for two other participants, reminding them of their belief that only wildlife were able to safely consume or come in contact with it. This contradiction suggests that participants had different expectations for the stream condition, one based on its ability to drain the land and the other based on safe human use.

Obvious human modification impacted both channel length and sinuosity, although some modifications, such as construction of new drainage ditches and channelization of existing segments, were more deliberate than others. Best et al. (1978) examined landcover change adjacent to Iowa stream channel segments before and after channelization and their findings suggest an explanation for the relationships we measured between natural areas and sinuosity. They found a direct relationship between channelization and adjacent perennial landcover; as channelization occurred, perennial landcover area decreased. This relationship was particularly apparent in open woodland and treeless pasture areas, with both likely to be converted to cropland. Applied to our results, this suggests that by the time of the 1939 photo date, efforts to channelize the most practical segments of the 1939 channel may have been completed and unsuitable land for cultivation was already in closed canopy forest, explaining the relatively stable mean sinuosity rating and high carry-over of closed canopy forest area between photo periods. Channelization of existing and construction of new first and second order channels in the upper reaches occurred next and was largely in place by 1958, expediting conversion of adjacent open woodland and grassland areas to cropland in subsequent photo periods.

Our stream length results and participants’ observations about changes in water levels and streambanks make an interesting comparison to other research characterizing change in baseflow in Iowa streams. Schilling and Libra (2003) studied annual baseflow, annual minimum flow for streams in two HUC-8 Des Moines Lobe ecoregion watersheds between 1940 and 2000, identifying significant increases in both attributes. Many channels become incised and widened as a result of increased baseflow drainage, suggesting the basis for participants’ descriptions of channel and streambank changes. These changes in channel width and depth, in proportion to the active channel, could contribute to resident perceptions of lower water levels and less flooding. However many discharge calculations, including annual base and minimum flow, measure a very narrow characteristic of overall stream flow and changes are not visually observable.

3.4. *Housing: “Acreages are sold off from farms for new homes”*

> J&C: Before the farms starting getting bigger, people lived on their farms. When the farms started getting bigger there were fewer families [owning the land] so then they starting renting out the houses and the farms. There were quite a few rented places around. Eventually [the houses] started falling down because they’d been standing there so long. Or they’d knock them down because their taxes would be less without a house on it.

Both U.S. Census data and our housing density change measurements in the rural portion of the study area support Jim and Carolyn’s account of many small, occupied farms and farmsteads during the years 1939–1940. The most striking change observable from the map analysis was the shift in rural housing density between 1939 and 1998. Measured rural housing density patterns shifted from one of relative uniformity in 1939 to one in 1998 where large areas of land were nearly uninhabited save for concentrated settlement areas that expanded in size (Fig. 5).

3.4.1. *“The farmhouses have gone down—completely under”*

The combined area of the three lowest density classes increased from 31 to 61% of total area during this time, particularly classes 1 and 2 (Table 4). The most common density class

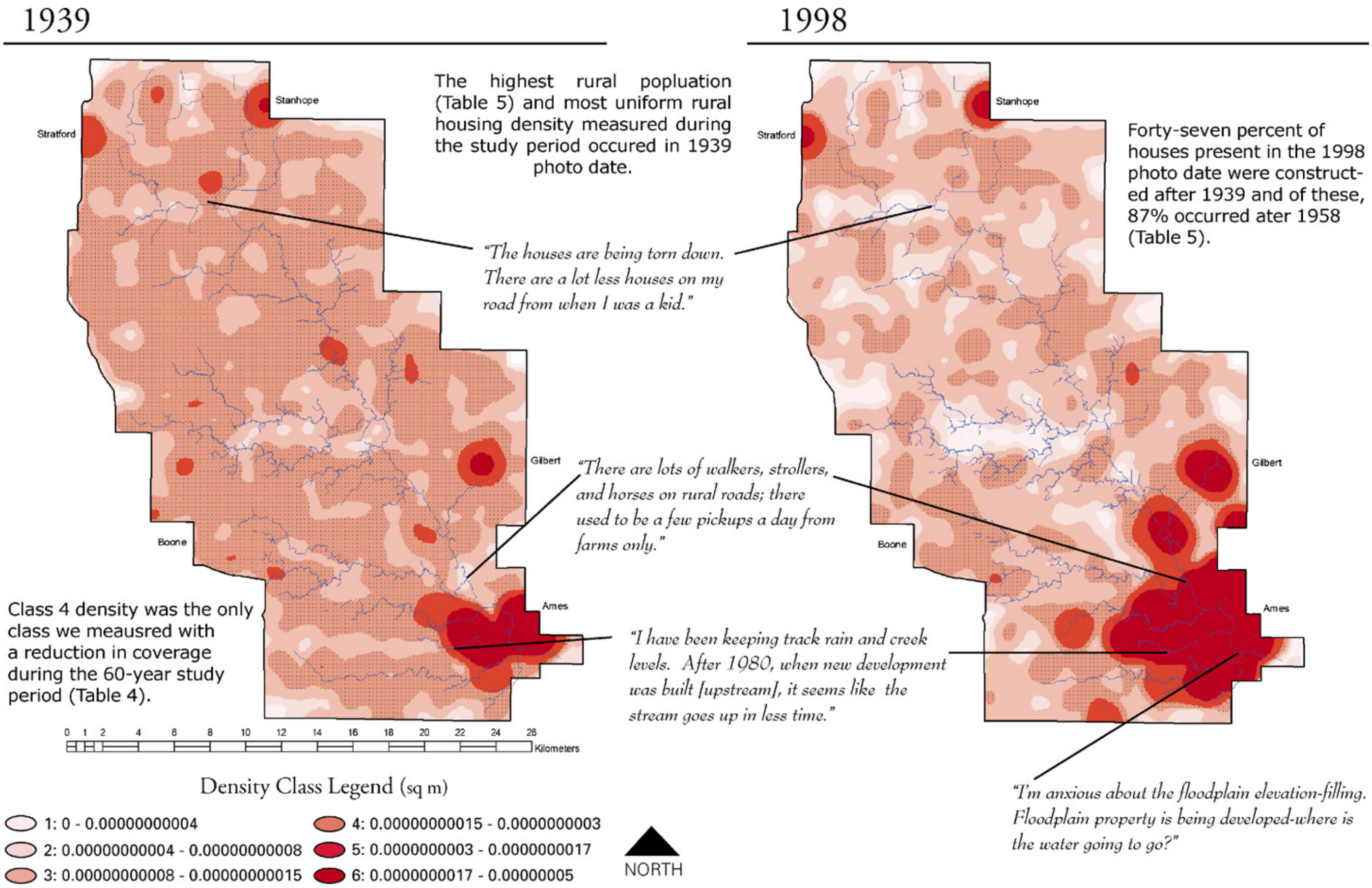


Fig. 5. Housing density change summary. Housing density results (units/m^2) illustrate variable conditions reported by residents. Map locations identify conditions matching those described in quotations (italics).

in 1939, class 4 corresponding with the range of approximately one house per 33–67 ha, declined 59% in area.

Participants in addition to Jim and Carolyn also noted the loss of farmhouses, but many more mentioned the growth of new rural homes unassociated with farming. Participants living in rural areas were more likely to perceive no change or less housing while participants in and near the city of Ames were likely to cite both urban and rural growth. This difference aside, participants had the most consensus on changes in housing and development of any element we assessed.

3.4.2. *"We don't know where these people come from"*

> J&C: Fifty-six years ago when we got married we could stand on this porch and see nothing but land and farm ground, and now we can stand here and see four houses south of us and we can see three across the road from us. They're taking out more and more [land for housing]. I mean, people want a little place to live in the country. Most of the houses around here were actually built in pasture and timber area and they didn't go into crop ground and build their houses. I mean, nothing was ever on it anyhow.

Table 4
Percentage surface area for each housing density class, 1939 and 1998

Density class	1939% of total	1998% of total	Total % change
1	1	5	+400
2	3	13	+333
3	27	43	+59
4	61	25	−59
5	5	6	+20
6	3	8	+166

Seventy-six percent of participant accounts concurred with Jim and Carolyn, perceiving an increase in housing construction and development in the study area. All these participants perceived development to be occurring in rural areas while only one-third mentioned urban growth. Our measurements identified both an increase in rural housing and urban development boundaries. The total number of houses measured in each photo date increased despite the removal of 33% of the houses identified in 1939 and a 39% decrease in rural population (Table 5). Class 5 and 6 density coverage increased in the rural portion of the study area, suggesting cluster-style development.

Despite an increase in rural housing numbers and participants' strong focus on them, a majority of the new housing units we measured occurred along the developed edges of existing communities. While areas of lower housing density expanded in the rural study area, urban development boundaries increased by 248% and population by 280% (Table 5).

Table 5
Urban and rural housing and population change measurements, by photo date

Measure	Photo date			
	1939	1958	1978	1998
Urban housing and population measurements				
Total housing units measured in photo date	1868	3205	5031	6862
Urban developed area (ha)	547.6	893.3	1141	1905.2
Urban study area population	13,918	28,485	47,878	52,952
Rural housing and population measurements				
Total housing units measured in photo date	1181	1224	1427	1522
Houses present in 1939	1181	1117	979	797
Houses added from previous photo date		107	351	335
Houses carried forward from previous photo date			97	390
Rural study area population	5586	4895	3734	3391
Rural houses constructed on each landcover from previous photo date				
Grassland cover		24	125	63
Open woodland cover		31	16	24
Closed canopy forest cover		11	11	67
Other landcover		41	199	181

3.4.3. *"Houses are taking beautiful wooded areas"*

Participants perceived that housing expansion inevitably led to other changes and impacts to natural areas and streams. Specific changes cited included builders' removal of understory and overstory vegetation for house construction, increased rural and urban traffic volumes, and more paved roads. One rural resident noted that their subdivision roads were paved recently, "As a result, runoff changed—I have seen gullies [along roads] grow deeper because of this."

Participants from all three counties, including Jim and Carolyn, discussed the landcover they perceived rural housing growth is replacing. Conversions from wooded areas, pastures, and farm fields were all mentioned. Fifty-three percent of all new rural houses we identified were constructed on land classified as "other" in the previous photo date's landcover analysis, suggesting cropland (Table 5). More houses were constructed on patches classified as "other" in each photo date than any other landcover. One city-county participant shared his perception about these changes: "The conversion of agriculture to housing isn't as prevalent as people perceive it to be. Housing growth has occurred and has a negative impact, but not to agriculture. There are over 50 platted lots a year on natural areas in my county, especially wooded lots." Remaining new housing units were located on former pasture (27%), closed canopy forest (11%) and open woodland (9%) patches. Large spikes in construction on grassland patches were noted in the 1978 photo date and in closed canopy forest in the 1998 photo date.

These data relate to other studies of housing density change in the region. In their study of housing density change in the Midwestern U.S.A. over the period 1940–1990, Hammer et al.'s (2004) methods, extrapolated from census data reports of housing age, identified the Ames area as growing rapidly during the 1970s. But this growth was an exception compared to the surrounding region, where their analysis showed our study area in the center of a large band of low to very modest growth extending from southern Minnesota down through northern Missouri.

4. Conclusions

The objective of this research was to explore the interface between measured biophysical change and the surrounding social context in the Central Iowa region over the past 60 years in order to suggest ways for social context and people to be more integrated in traditional assessment data. We identified fundamental differences between traditional biophysical landscape change assessments and how residents experience and interpret change and, utilizing the tension created from superimposing the two types of data, suggest changes in assessment structure and sequence, metric construction, and data sharing.

The GIS assessment of natural areas, stream length and sinuosity, and housing density yielded fine-scaled statistical information comparable across both the photo periods in the study area and the findings of other quantitative assessments of this type. Our stakeholder interviews in many cases corroborated these quantified measures and, as expected, illustrated a range of interpretations and experiences.

While across our purposive sample of 58 participants we feel we attained a broad range of how people perceived landscape change in the region, we believe that differences in interpretation suggest that people's expectations and baselines for comparison differ. Some of the dramatic changes revealed by the GIS assessment drew little notice from most stakeholders. These changes predominantly had to do with what was no longer present on the landscape—ditches and minor streams that had been sunk to underground drains, and farmsteads that have disappeared from an increasingly depopulated rural countryside. In some cases these patterns were made visible only through temporal analysis, but in other instances perceptions of change were found to vary as a function of where one lived within the study area, the nature of one's relationship with the landscape, and the length of one's residency.

We found people to be intuitively curious about and interested in landscape change and their interpretations of change to be a fairly complex phenomenon. While our GIS measurements were carefully structured to isolate change measurements in individual metrics and separate meaning from that being observed, many study participants did not perceive or interpret change in this way. In contrast, change perceptions were often interrelated, such as the connection identified between fencerow removals and the loss of specific bird species.

Knowledge of change was generally verified through experience, including changes participants made on their own property such as cropping distance to stream edge, direct observation such as roadside mortality, and focused monitoring of conditions such as stormwater discharge. Similar to Zube et al. (1989), we found that change experiences were most often linked to familiarity—with their own property, neighboring properties, or along frequent driving routes. When asked to contemplate change at the watershed scale, participants often struggled to respond. Additionally, not all metrics were reported with the same confidence. Visible stream conditions in this region, such as water level and turbidity, often fluctuate daily compared to changes in natural areas and housing, and participants' lack of confidence in reporting stream changes may be related to this.

Most interpretations of change carried an evaluative weight to them, often dualistic and rooted in each participant's values: landscape change did not just happen, it sometimes happened for the better but more often for the worse. This evaluative perspective not only colored the data regarding landscape change, but also directed stakeholders to focus on attributes of change that the quantitative assessment did not. This was particularly true with our stream assessment; few participants mentioned or related to changes in stream extent and sinuosity, but instead talked extensively about stream flow and water quality. Data to interface with these perceptions is complicated because either some metrics used traditionally in discharge measurements are more finely tuned than those used by participants (stream flow) or because of limitations in monitoring data (water quality).

We found the interface between landscape change and its social context to be spirited and complex. Of the possible motivations to integrate these two types of data in structuring landscape assessments, we focus our conclusions on two planning applications: non-participatory assessments where data are intended to convey technical findings to regional stakeholders, and participatory assessments that integrate multiple audiences into process and data.

Regardless of the level of participation, landscape change assessments should produce data that are within the realm of direct public experience or are capable of being translated in ways that have meaning and relevance to people. In most cases non-participatory assessments are still subject to review and feedback by public stakeholders, including local planners and decision makers, and if these data are to be useful beyond quantifying and modeling change in research applications, they must be capable of being explained in meaningful terms.

Participatory assessments, where residents are directly involved in the development and application of the assessment, have the ability to convey information throughout the assessment process, rather than only presenting results at the end. Our results suggest the sequence of assessment stages and the forms of data input and review are important considerations. To improve upon our research design in future work, it would be more effective to sequence the social assessment prior to biophysical assessment to allow public involvement in the actual development of change metrics. Metrics relating to local values could then be integrated with metrics also identified as important to by hydrologists, engineers, and planners. A socially constructed metric in our study area may have focused on estimates of changes in migratory and resident bird population and diversity over time relative to the landcover present in each photo date. In this way, the language and resulting data speaks to audiences beyond planners and researchers and relates to the regional public (e.g., Hull et al., 2003).

We believe integrated assessments as described in this paper hold promise in contributing to an improved understanding of landscape change. The now-defunct Clear Lake appears as a pasture (1939) or a crop field (1998) on historic aerial photographs, a subtle ring of scattered trees outlining the historic limits of the pothole landform in each photo date. Alongside the local 1907 newspaper account presented to us during an interview, however, the social meaning and struggle of change on this currently nondescript parcel are brought to life. And just as participants were unable to separate change assessment from evaluation, the social record of Clear Lake is a reminder that none of the landscape changes we measure come without local and regional effects to economies, ecology, hydrology, and identity.

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