An Ecological Restoration Model: Application To Razed Residential Sites

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ABSTRACT: A model to guide ecological restoration of damaged sites within natural areas is presented. The objectives of the model are (1) to institutionalize the restoration project; (2) to provide guidelines for long-range project planning and communicate project objectives and methods to restoration participants and the natural area's constituency; and (3) to promote ecological restoration as a research method and learning tool. Application of the model is demonstrated by presenting a case study of restoration of residential sites at the Indiana Dunes National Lakeshore.

INTRODUCTION

Land is one of our most important natural resources. As the human population has increased, disturbance to land has also increased, leaving large areas unsuitable for productive use (Bradshaw and Chadwick 1980). The degree of disturbance ranges from complete devastation of the soil and vegetation (e.g., strip mining) to only removal of native vegetation, leaving the soil intact (Aber 1987). In natural areas, the objective is to restore a disturbed site to a condition resembling the potential native communities. This task requires the joint effort and expertise of engineers, soil scientists, agriculturists, ecologists, and government agencies.

The goals of restoration range from site stabilization to prevent adverse impacts on surrounding areas, to the return of the site to a functioning system dominated by native taxa. The latter, here termed ecological restoration, is the subject of this paper.

The successful restoration of a disturbed site is dependent on a thorough understanding of the ecology of the site and the materials (plants and animals) to be used (Bradshaw 1984). Yet the business of developing, manipulating, and reconstructing disturbed land has been done as a landscaping exercise rather than an experimental manipulation. Ecologists have often missed the opportunity to contribute to the science of restoration and to test ecological ideas in practice (Bradshaw 1987a). As stated by Harper (1987), the aim of ecology is "the development of an understanding of the workings of nature that would enable us to predict its behavior and to manage and control (conserve or change) it to our liking." Ecologists have busied themselves with dissecting nature when the acid test of understanding is putting it back together (Bradshaw 1987b). Restoration can be a win-win process if properly designed. When restoration is successful, a degraded piece of land is returned to a more natural state. When restoration fails, one can learn more about how ecosystems function (Ewel 1987).

The objectives of this paper are to present a model for ecological restoration and demonstrate its application by presenting a case study of restoration of razed residential sites at the Indiana Dunes National Lakeshore.

THE ECOLOGICAL RESTORATION MODEL

This model was formulated by the author following five years of research on vegetation recovery in razed residential sites at the Indiana Dunes National Lakeshore. At this time, park management began asking for application of what was learned to actual site restoration (Figure 1). The purpose of the model was to guide a long-term restoration program despite an expected rapid turnover in park personnel. It included a blending of ingredients from models of Bradshaw (1984) and Bradshaw and Chadwick (1980), with additions and modifications based upon personal experience and management principles.

A basic premise of ecological restoration and this model is to fix only what's broken. The process is analogous to a mechanic repairing a car. The first requirement is for the mechanic, or ecologist, to have a good knowledge of the system's form and function. This allows diagnosis of what's wrong

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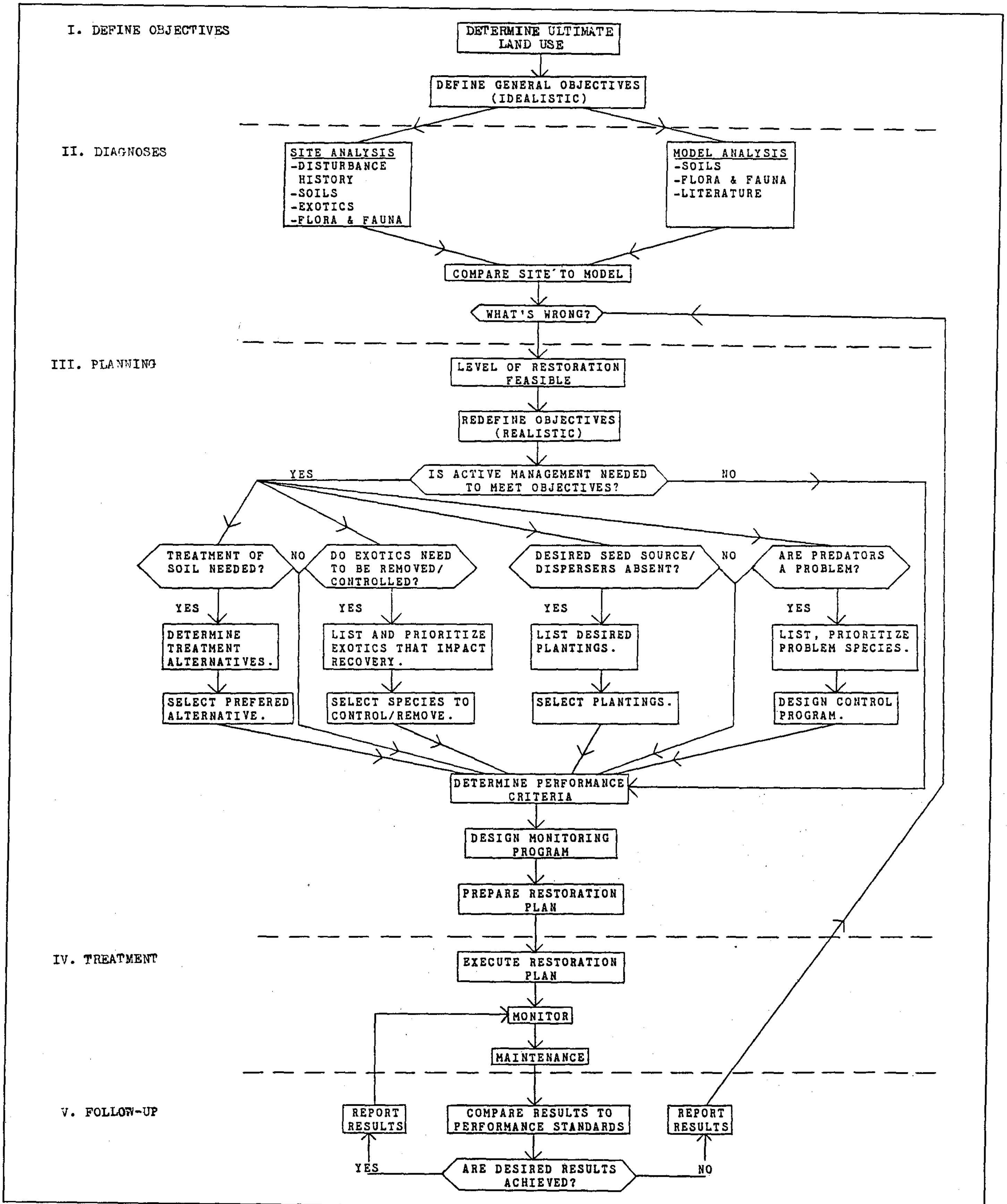

FIGURE 1. A model for ecological restoration.

with the malfunctioning system by comparison with a functioning system. Based upon the mechanic's knowledge and technical skills, repairs are made by removing, restoring, or replacing components. The system is then monitored to determine if the desired result was obtained. If so, a malfunctioning system has been restored. If the system still doesn't work, an error in diagnosis or treatment is indicated. Further analysis is needed to identify additional problems. When this procedure is applied to land restoration, one's general knowledge of ecology increases and new technology is developed.

The model consists of five basic steps. The first step is to define the objectives of the restoration project. It is difficult to progress if you don't know where you are going. The second step is diagnosis or analysis of the area to be restored. The process usually involves the selection of a natural area similar to the disturbed area and a comparison of the two.

Based upon this comparison, plans are made to replace missing components, remove unwanted parts, and repair what can be. Unlike the repair of an automobile, reliable tools and technology have not been developed for ecological restoration. Often one does not know what the critical components are or what is the function of various parts. Therefore, it is important to select alternative approaches and document their effectiveness (technology development). Further, if one is to compare various restoration schemes, performance criteria must be established and appropriate measurement techniques employed.

The next step is to execute the plan, adhering to the protocols established. The effects of each treatment are monitored and documented. Any deviation from established protocols must be recorded along with any uncontrolled factors (e.g., climate) that could affect various treatments.

The final step is evaluation of the various treatments. If all indications are that a certain treatment is successful, the information should be shared. If treatments did not have the desired results, they should be analyzed to determine why. It is important, to share negative results—one generally learns more from mistakes than successes.

MODEL APPLICATION: A CASE STUDY

A case study of the ecological restoration of residential sites at the Indiana Dunes National Lakeshore is presented to illustrate application of the model.

General Objectives

Most parks and reserves are set aside to preserve a piece of "nature." The U. S. National Park Service has operated under the premise that the perpetuation of natural ecosystem processes is the best approach to accomplish this goal. However, most parks are only fragments of ecosystems; often natural ecosystem processes have been interrupted, major components of the ecosystem are gone, exotic species have been introduced, or habitats have been destroyed by past and present land uses. Therefore, the perpetuation of nature requires restoration of degraded sites and active, continuous management of relatively natural sites. Such is the case at the Indiana Dunes National Lakeshore. Although the area still supports high diversity of plants in unique associations, natural processes such as dune building and fire have been forever modified.

One major impact here has been from low-density residential use. Over 700 residences were within the boundaries of the lakeshore when it was established in 1966, of which 365 remain occupied. Impacts caused by this land use include removal of native vegetation, the introduction of exotic species, and the modification of the structure and chemistry of the soil (Hiebert and Pavlovic 1987). These anthropogenic impacts distract from, and in many cases threaten, the continuance of the unique dune ecosystems.

The ultimate land use and general objectives for restoration are provided by the park's general management plan (National Park Service 1981). Most residential sites are found within areas of the park designated as "natural zones" where the priority is restoration/preservation of the native fauna and flora, and nature study is the anticipated future land use. The specific objective for abandoned residential sites is to direct and accelerate revegetation with native species. Based upon this general objective, our idealistic objective is to influence vegetation change in residential sites so that in 30 years species composition, species richness, and community structure are indistinguishable from that of naturally caused gaps in the surrounding native vegetation.

Diagnosis

Results from research on 12 residential sites, 3 to 11 years after abandonment, surrounded by black oak (*Quercus velutina*) woodlands revealed large differences in species composition and species richness compared to the surrounding woodland (Hiebert and Pavlovic 1987). A total of 153 taxa were encountered; these included exotic and native species common to old fields, residual horticultural species, and species common to the surrounding woodland. High variation in species composition was observed among sites. However, higher variation was observed among areas within a site exposed to specific land uses in the past (e.g., drive, building site, lawn, or garden). Species composition was more similar to the surrounding woodlands in 9-year-old and 11-year-old sites than it was in 3-year-old sites. However, the similarity in species composition among past land uses was consistently lower in 9-year-old versus 3-year-old sites.

Species richness was higher in abandoned residential sites than in surrounding oak woodland. However, species richness was lower in 9-year-old and 11-year-old sites than it was in 3-year-old sites.

The difference in species composition in abandoned residential sites compared to the woodland reflected the difference in degree and time since the last major disturbance and the composition and extent of residual horticultural species. The differences among sites was the reflection of the differences in site size, seed source, and residual vegetation. The differences among past land uses within sites reflected the degree or type of disturbance caused by the various past land uses. Drives were usually gravel (limestone); highly compacted; high in pH, calcium, and cation exchange capacity (CEC); and low in organic matter and water holding capacity compared to the native soils. Native soils of the area were sandy and thus low in nutrients and water holding capacity, so topsoil was usually added to support lawns and gardens. Thus, nutrients and organic matter were high in lawns and gardens relative to native soils. Soon after abandonment, gardens became dominated by *Solidago* spp. with little species turnover. Lawns were relatively closed to the establishment of new species due to a dense sod of *Poa pratensis* or other lawn grasses. House sites were open to invasion but low in nutrients and organic matter relative to native soils. However, organic matter and nitrogen levels were higher and more similar to native soils in 9-year than in 3-year-old sites.

Most residential sites were less than 0.3 ha in extent with native vegetation present within or on one or more site edges. It was therefore assumed that an adequate seed source of native species was available, an assumption supported by the presence of many of the local native species within three years of abandonment in these residential sites. However, some exozoic woody species (species whose seeds are dispersed but not ingested by animals; e.g. *Quercus* spp.) were not present unless a seed source was available within the site or at the site border. It was also assumed that native animals, some of which are important pollinators or seed dispersers, and soil microflora would be able to colonize the sites because they were present in the adjacent woodland. It was also assumed that predators were not interfering with the recovery process. The validity of those assumptions, especially the latter, needs to be investigated.

Many exotic species had been introduced (deliberately or by accident) to the residential sites. Exotic species were categorized based upon their observed and potential effects on the recovery process (Table 1). There were horticultural species that were persistent but which did not spread (e.g. daffodils, iris, etc.). The primary effect of leaving these exotics is that they provide a long-term reminder of the area's past residential use. Another category was long-lived species that did not spread but which retarded succession for the lifetime of the individuals. Other perennial species reproduced, spread, and retarded succession or invaded the surrounding native vegetation. These latter species must be removed if the restoration objectives are to be met.

In summary, what was wrong in abandoned residential sites was that native species had been removed, exotic species had been introduced, and the substrate had been modified in different ways by specific past land uses within a site. What was (assumed to be) right was that most of the desired seed sources, pollinators and dispersers, and soil microflora were present in the adjacent woodland and could easily colonize the restoration sites.

Planning

Based upon the above information, what level of restoration is feasible? If the logic employed was sound and all significant problems have been identified, fixing that which was identified as being broken should have the predicted and desired effect. If sufficient support is available, the prognosis will be good for approaching the original objective.

It appears that active management will be required to meet the stated objective. The information provided by the investigation of 12 abandoned residential sites indicated that each site will present unique challenges

Table 1. Persistent exotic species which retard or modify succession or invade surrounding native vegetation.

A. Woody species with little or no reproduction that retard succession.

Forsythia spp.	*Pseudotsuga menziezii* Franco
Juniperus spp. (ornamentals)	*Pyrus communis* L.
Ligustrum vulgare L.	*Pyrus malus* L.
Picea abies Karst.	*Spirea prunifolia* Sieb. & Zucc.
Picea pungens Englem.	*Syringia vulgaris* L.
Pinus nigra Arnold	*Taxus* spp.
Pinus sylvestris L.	*Vinca minor* L.

B. Woody species that reproduce frequently and retard succession and/or invade native vegetation.

Ailianthus altissima (Mill.) Swingle	*Morus alba* L.
Alnus glutinosa Gaertn.	*Populus nigra* Muenchh.
Berberis thunbergii DC.	*Robinia pseudoacacia* L.
Lonicera japonica Thunb.	*Rosa multiflora* Thunb.
Lonicera tartarica L.	

C. Grasses and herbs that retard succession and/or invade native vegetation.

Agropyron repens (L.) Beauv.	*Euphorbia maculata* L.
Bromus inermus Leyss.	*Festuca elatior* L.
Bromus tectorum L.	*Hieracium pratense* Tausch
Cirsium arvense (L.) Scop.	*Melilotus alba* Desr.
Cirsium vulgare (Savi) Tenore	*Melilotus officinalis* (L.) Lam.
Convolvulus arvensis L.	*Poa pratensis* L.
Croton glandulosa (Muell.) Arg.	*Taraxacum officinale* Weber

but that it is possible to generalize treatments for specific past land uses (lawn, garden, etc.), though not for residential sites in general. If active management is not taken, the objective most likely will not be realized.

In the case of the residential sites in oak woodlands, modification of the substrate and the introduction of exotics were considered the most significant impacts to be addressed. In some cases, the lack of desired propagules and seed dispersers and an overabundance of predators are potential problems. For example, white-tailed deer populations had increased at least fivefold in the last ten years. The edge associated with low-density residential use creates ideal deer habitat. Experiments are now being designed to determine the effects of deer browsing on the establishment of desired species. In residential sites where the water table is near the soil surface, hydrological considerations become important. The model should be modified to reflect this for lowland sites.

At all sites, it is mandatory to remove those exotic species that interfere with the desired revegetation process or invade the surrounding oak woodlands. The restoration plan should include alternative methods of removal or control to allow comparison of effectiveness and side effects.

Alternative treatments to mitigate impacts of specific past land uses on the substrate are presented in Table 2. As is normally the case, a preferred mitigation alternative must be selected prior to evaluation of the effectiveness of treatment alternatives. Therefore, a preferred alternative should be selected based upon its feasibility of success, and economic and logistical considerations. Other alternatives should be tested on an experimental basis. This is a 20-year (or longer) project, so if an alternative other than the one selected proves more effective, it can be substituted at any time.

Determining performance criteria has been one of the most difficult steps in ecological restoration. The most often employed criterion has been the resemblance of the restored area to the model. Ewel (1987) suggests that performance criteria should also address the sustainability, invasability, productivity, nutrient retention, and biotic interactions of the restored area. It is difficult to consider all of these criteria, especially in the short term. One approach is to set short term (one-to five-year) criteria addressing specific goals of a treatment (e.g., did the treatment eliminate exotic lawn grasses?) and longer term criteria addressing the above factors.

With the above information, the number of sites to be restored, and a timetable (Table 3), a strategic planning exercise was conducted involving all of the probable players (e.g., the roads and trails foreman, the contracting officer, resource management specialists, researchers, and park managers) in the restoration program. This not only provided the opportunity for input from individuals with varied expertise but also created a feeling of project ownership by all involved. An overview of the research results and management objectives was presented. Participants were then divided into working groups and asked to draft restoration objectives, tasks to approach the objectives, designations of responsibilities, and a draft schedule.

FUTURE MODEL APPLICATION

A restoration model was designed to guide the restoration of residential sites at the Indiana Dunes National Lakeshore. However, the basic components and chronology (define objectives > diagnosis/analysis > planning > treatment > follow-up) should be applicable to most restoration projects.

Table 2. Objectives and alternative treatments to restore substrates in residential sites at the Indiana Dunes National Lakeshore.

PAST LAND USE	RESTORATION OBJECTIVES	TREATMENT ALTERNATIVES[1]
Drive	- reduce soil compaction	- stratify
	- decrease pH, Ca, and CEC	- stratify and fertilize
	- increase OM, N, and P	- remove gravel
		- remove gravel and replace with native soil
Garden	- decrease OM and N	- remove top soil
	- increase species turnover	- remove vegetation
		- remove top soil and replace with native soil
House	- increase OM, N, and P	- fertilize
		- fertilize and mulch
Lawn	- remove exotic grasses	- remove sod
	- reduce OM and N	- herbicide
		- herbicide followed by fire
		- fire

[1] In all cases, a "no action" alternative should be included to serve as a control.

Table 3. List of residential sites at the Indiana Dunes National Lakeshore by year of termination of use agreements—homesites available for razing and restoration.

Year	Number of sites[1]
1989	10
1990	11
1991	2
1992	2
1993	15
1994	42
1995	75
1996	40
1997	12
1998	26
1999	14
2000	14
2001	32
2002	5
2003	4
2004	4
2005	3
2006	9
2007	18
2008	6
2009	8
2010	13
Total	365

[1] Approximately 400 sites were razed prior to 1989. These sites also require restoration.

Well-defined objectives serve as the foundation for all project planning and evaluation. For ecological restoration, the objectives guide selection of the ecosystem model to which the site to be restored is compared. The objectives also determine which factors need to be addressed in the diagnosis stage. In addition, the objectives guide the selection of performance criteria and the design of the monitoring program.

Factors to be considered in the diagnosis and planning stage can be modified to fit the specific restoration project. However, the factors listed are considered a minimum. In some instances, a suitable site model does not exist in situ or in the literature. In these cases, defining objectives requires imaginative approaches.

Further, as ecological restoration as a discipline is in its infancy, it behooves us to approach each project as an opportunity to learn and refine techniques. Therefore, all projects should be designed to ensure measurable and interpretable results. Testing multiple restoration alternatives will speed the accumulation of information and increase the probability of successful restoration.

Finally, if ecological restoration is to advance as a discipline and a technology, results must be effectively communicated. As stated above, it may be more important to communicate results of restoration experiments that did not fit predictions than to report those that do.

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