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Revised Literature Review

Implications of Reforestation: Controlling Deer Browsing And Competing Vegetation

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Scope of Review:

The purpose of this literature review was to gather and interpret control methods used in the past, in order to make suggestions for future ecological restoration work at Fernald and to help provide a background for interpreting results from the current restoration project. Papers considered for this review dealt with browsing and/or "weed" competition which impact the restoration of hardwood deciduous tree species. Although there have been fairly exhaustive studies dealing with conifer regeneration and restoration (especially in the western states), there were surprisingly few in-depth studies concerning hardwoods. Literature concerning conifer related problems were not generally included in this review since they are not relevant to the work at Fernald. There are few similarities one can draw when comparing conifer and deciduous tree establishment because of the vast differences, anatomy, morphology, growth rates, and palatability. The current tree restoration project will provide valuable information to fill in what appears to be a gap in our knowledge concerning deciduous tree restoration.

Introduction:

In recent years the number of reforestation projects have increased due to growing appreciation and concern for the ecological significance of forests. Benefits of forests include reducing soil erosion, maintaining biodiversity, reducing the effects of global warming, and providing recreation and educational places for people (Shea & Stange 1998). Reforestation is an endeavor to improve the condition of land and to speed up natural succession by planting trees on old fields and cleared land. During the period between disturbance and reforestation, competitive vegetation, disease or pests, and environmental stresses are some factors that can influence natural succession and complicate reforestation projects. Not only can these factors influence tree establishment, studies have also indicated that the presence of forage animals (such as mice, rabbits, and deer) can be a major impediment to forest establishment and natural succession (Tierson et. al. 1966, Alverson et. al. 1988, Canham et. al. 1993).

Two common complications of reforestation projects, competing vegetation and browsing, are concerns in most cases where deer density is high and sites are old fields where vegetation, excluding trees, have been allowed to grow. Perhaps their importance is also due to their large role in determining the success of projects and that the fact that they can be easily manipulated (such as with vegetation removal and fencing). The first part of the review specifically focuses just on the effects of deer populations; these studies did not use exclosure devices, but observed damages in natural sites. This section also includes a brief discussion on edge effects, preference, and timing of browsing is presented. After general information on browsing, techniques for control of browsing and competing vegetation are discussed.

Deer Browsing:

Work with natural populations has shown that the effects of browsing by white tailed deer (*Odocoileus virginianes*) can be severe enough to lessen the relative density and regeneration of forests in the temperate North America (Heinen & Sharik 1990). Browsing can decrease the growth, overall biomass, and the survivability in seedling populations. Also, browsing can lead to the development of compact saplings, with unequal growth, large branches and small leaf biomass (Van Hees et. al. 1996). The damage done by browsing largely depends on tree species, intensity, and the longevity of browsing.

In a study of tree seedling establishment in an Ohio deciduous forest Boerner and Brinkman (1996) recorded that of 2,553 seedlings monitored, over a ten year period, only two grew out of the seedling size during the time of observation. There was also a high mortality among the seedling population, less than 2 percent of the seedlings persisted for more than 2 years. Although many factors can be accounted for the low survivability rates (such as low light stress, drought, and seedling competition) the major cause of failure was attributed to observed tip browsing by white-tailed deer.

Research by Heinen and Sharik (1990) reported a change in preference in tree species over a 5-year period. Although there was a switch in choice, browsing still resulted in high mortality. Regardless of palatability, after 5 years, 305 trees were sampled, 42 percent trees were dead, and of that percent, 99.2 percent had been browsed. Also an important measure of the severity was the reduction in the average number of trees per study plot. After 5 years the average decreased by 84 percent, that is, from 40.1 in 1983 to 6.5 in 1988. The reduction in overall stem density is related directly to deer browsing. In contrast, typical reductions from seedling to maturity (as opposed to 5 years) would be roughly 75 percent.

Not only can browsing significantly reduce the growth and the survivability of seedlings, but it can also reduce tree seed germination. Using an exclosure treatment, browsing of all of the species (including five hardwood species) by deer hindered the germination of the seedlings (De Steven 1991a). Results indicated that all study species were affected. Larger-seeded species suffered significantly greater predation when compared to the smaller-seeded species.

Browsing Intensity, Timing and Preferences:

Vegetation surrounding reforestation projects, especially forest edges, often provide ideal habitat for white-tailed deer (Alverson et. al. 1988). Deer tend to browse the woody twigs of plants near forest edges and may, in this way, be an impediment to reforestation projects (Alverson et. al. 1988, Inouye et. al. 1994). Many factors, already mentioned, determine the effects of browsing, but also important is the intensity and longevity of browsing. White-tailed deer in the United States tend to browse in agricultural areas where vegetation and cover are high. Ferns, grasses, and other herbs are important source of food before leaves appear on woody plants (Healy 1971). They feed on leafy vegetation in agricultural fields and on understory growth in hardwood forests. After the crop in the fall is harvested, deer feed mainly on woody plants. Other research has shown that timber species are an important food year-round (8.7 to 45 percent of feeding time). Tree leaves are generally eaten from spring through early fall and terminal buds were more likely to be consumed during the winter months (Healy 1971).

Differential browsing among tree species has been reported by De Steven (1991b) where 1.5-2 m high fences with wire barriers were used to exclose deer. The growths of all species after 36 months were significantly lower outside the exclosure when compared to growth within the exclosures. Damage varied in intensity between the species. For example, winged elm (*Ulmus alata*) was repeatedly grazed to ground level, which extremely reduced growth and survivability. However, only stem tips were browsed on white ash (*Fraxinus americana*) and sweet gum (*Liquidambar styraciflua*), which resulted in reduced growth, but did not affect survivability. Unfortunately, we did not find any broad comparison studies that related mortality with the percentage of deciduous tree tissue that was removed by browsing.

The timing and significance of browsing can also effect the growth and survivability of tree establishment. Extreme cold and snow can reduce the movement of deer and further intensify the browsing on seedlings in a small area. The effects of winter browsing on regrowth the following spring depends largely on the arrangement of the buds along the stem and the ability of the lateral meristems to develop if the terminal meristem is removed (Canham et. al. 1994). Some species, such as northern red oak, have concentrated carbohydrate reserves in the root system during the winter, and therefore are less sensitive to winter browsing (Gordon et. al. 1994).

In a study simulating browsing, Canham et. al. (1994) compared the effect of varying and intensities of "browsing" in winter and in summer. The season of browsing, intensity and frequency of browsing, light environment, and species of tree all produced various responses. Although 1 or 2 years of severe browsing may have a little effect on survival (Canham et. al. 1994), the danger with repeated browsing is that it will eventually deplete seedling reserves and lead to seedling death (Shea & Strange, 1998). In contrast to winter browsing, Canham et. al. (1991) also found that summer browsing in similar levels of intensity could cause significant increase in mortality and decrease in height. Again, seasonal browsing may vary with tree species and their physiological responses to browsing. For example, one tree species grown in the above experiment, white ash, summer clipping had greater effects on fall root starch reserves when compared to the other tree species in the experiment. This suggests that white ash regeneration would be affected greater by browsing than others. This short-term study did not find significant connection between light intensity and seedling response to clipping; but they do suggest possible long-term reactions. There may also be an advantage of high-light that would allow seedlings to grow quickly above the browsing height of the deer, regardless of the frequency of browsing.

The question of whether deer herbivory on young trees can be reduced if deer are provided with an "alternative" food source was also examined. There are no scientific studies, published to date, that have experimentally tested this question. There are however, many studies and Wildlife Biology textbooks concerning deer herd management. All studies refer to the "carrying capacity" of the forest or park. There is a direct relationship between the nutritional quality and quantity of forage material and the number of offspring produced each year and the overall size of the deer.

Although it is possible to provide a forage that will attract and sustain a deer herd (Imperial Whitetail web site), the deer population would quickly increase and overrun the "alternative" or "enhanced" food supply. This may be a viable alternative if some type of hunting or predator was introduced at Fernald. Although there have been some regional reports of "wild" dog packs that regularly kill deer, I do not know of other predators present at Fernald. Providing a special forage crop would enhance the nutrition of the deer, and would result in an even larger deer population than is currently on site.

Fencing, Exclosures and Repellants:

Most of the research dealing with controlling deer use exclusions (such as fencing) for concluding deer browsing habits and their affects on tree growth. In studies assessing the affects of vegetation, unwanted herbaceous plants were removed by various methods such as herbicides, and in some cases, suppressed by material like mulch. Many of the studies reviewed had tested both the effect of browsing and competition removal to see if both of these practices could be used in conjunction to improve tree establishment.

Since reforestation depends greatly on the growth and survival of seedlings, devices such as tree shelters, fencing, and deer repellents have been tested in their ability to control mammalian browsing. Tree shelters are tubes or fencing that wraps around a sapling or seedling in order to make the tree unavailable to the deer.

As observed by Marquis (1977), tree browsing by white-tailed deer resulted in complete reforestation failures, and the only way to succeed in regeneration is to protect the seedling from browsing. In this study, seven devices were tested over five years to evaluate cost and effectiveness. An experiment conducted by the Northeastern Forest Experiment Station indicated that protection with tree shelters varies with the diameter and the mesh covering used (plastic or wire). It was concluded that small mesh plastic and wire tubes were fully effective (over 90 percent) when used in a 1-foot diameter, surrounding the tree. Both types need to be at least 5 feet tall in areas of high browsing. The plastic protectors were more expensive, but faster to fabricate and added an additional advantage of providing protection from rodents. Metal mesh lasted longer than the plastic, and wooden stakes were problems in longevity in each type of protection (Marquis, 1977). Recently Shea and Stange (1998) determined that seedlings protected with white plastic tree shelters (5 feet tall) were free from browsing and were significantly taller than the unprotected seedlings. By using tree shelters to allow the trees to grow above the range height (browse line) of deer browsing, experiments have shown increased growth and survival rates of seedlings within exclosures.

Tree shelters are generally easy to install and take some maintenance, but they do have a few drawbacks. They are fairly expensive and may be impractical for large reforestation projects, because they can be used only once and must stay in place for at least two years after the trees emerge from the top and develop sturdy stems (Kittredge et. al. 1992).

Other possible alternatives for decreasing the intensity of browsing include electrical fences and topical repellents. The use of fencing has proved to be a very effective way to exclude deer from plantings, increasing growth and survival of trees and other herbaceous plants. Tierson et. al. (1966) fenced in two areas with a heavy gage, measure wire fence, 10 feet high. After nine years, the 2-acre plot fenced in resulted in growth of three important hardwoods (sugar maple, birch, and white ash). Inside the exclosure there were 5,290 stems of these three species per acre, 3 feet and over in height. Outside the exclosure, there was a completely inadequate stocking in this height class. Where trees were unprotected, there were no yellow birches over 3 feet recorded, and only 167 stems per acre (stems referring to trees of varying classes from 3 feet and up) of sugar maple and ash.

Marquis and Grisez (1978) also used fencing to exclude deer and found significant difference between the fenced and unfenced areas. The major effect of fencing was the increase in growth in height of the surviving seedlings. After 6 years, 56 percent of fenced in plots contained trees over 3 feet tall, and 84 percent contained stems over 1 foot tall. Compared to before fencing, there were few seedlings over 1 foot tall. Similar results in increase in height and survivability using fencing as deer exclosure have been found by Palmer et. al. 1985, Alverson et. al. 1988, Canhan et. al. 1993, Inouye et. al .1994.

As an alternative to the traditional woven wire barrier fence (considered to be deer-proof but too expensive for agricultural uses), electrical fences may provide a more cost effective way of repelling deer; but they may also need more maintenance (Palmer et. al. 1985). Many fences are available to exclude deer, but the importance lies with the wiring spacing and configuration of an effective fence and must prevent deer from crawling under and going through the fencing structure. The most successful electrical fence tested by Palmer et. al. (1985) was "The Penn State Vertical Electric Deer Fence" which has five wires spaced approximately 11 inches apart, with the lowest wire spaced smaller to prevent deer from going under the fence. Figure 1 illustrates fences tested by Palmer et. al. The more traditional agricultural fences with woven wire, and high-tensile fences (which have high voltages, but higher wire tension than traditional electrical fencing), varying in design, but have been proven effective if they are at least 8 feet tall (Palmer et. al. 1985). The 4x4 galvanized fencing can be purchased in 8-foot high sections, but it generally has to be special ordered.

Repellants:

In areas where other forms of control such as shelters and fencing are impractical, chemical repellents are often used. However, the majority of chemicals repellents are either ineffective or reduce damage slightly. Repellents with biological bases, such as predator urines (bobcat, coyote, and human), have been tested in their ability to decrease browsing by white-tailed deer (Swihart et. al. 1991). Results indicated that out of three predator urines used (topical sprays reapplied at weekly intervals during the winter season), bobcat urine was the most effective (possibly due to the styles of hunting and the predator and prey relationship). Browsing percentages decreased to less than 40 percent for very palatable species, but had no significant effect on less palatable species. Because deer did not react with non-predator urines (such as rabbit, used in this study), this suggests that herbivorous mammals can distinguish predator odors and therefore adjust their behavior. Since the urine was applied as a spray, it may also function as a taste repellent.

Because biological methods are not always acceptable or easily obtained, organic compounds have been identified and synthesized. Synthetic repellent made from an amino acid found in the urine of domestic cats and from lion feces have been manufactured, but documentation of their repellency was not found. The identification and synthesis of active repellent compounds found in glandular secretions of predators and the development of slow release devices to enhance the long term effectiveness of the compound would benefit further research in this area. Fermented eggs, containing amines and volatile fatty acids that are found in anal gland secretions of canids (any animal in the dog family) are also available to use for deer repellency (Swihart et. al. 1991).

There are several company web sites, which deal with predator urine and chemical repellants. The majority of these sites refer to customer testimonials or garden magazine descriptions. All companies were contacted and asked about rotating brands. All of the companies responded by saying that it would be unnecessary if you were using *their* product. We also asked about any scientific data, and were told that it was "proprietary".

One of the companies referred to a 4-year study that was conducted at Rutgers University but was unable to provide a reference, year, or investigator name. I contacted two ecologists at Rutgers and neither of them knew of such a study. The results of this work have certainly not been published in a peer-reviewed journal or it would have been located during the library search.

While reading through some of the "testimonials" offered by the companies producing predator urines, it appeared that specific urine was only effective if the deer herd were actually exposed to the predator. For instance, coyote urine was more effective than bear urine in locations where coyotes ranged. Although there have been reports of coyote and bobcats in our area, it is doubtful whether the "Fernald deer" are actually attacked by either predator.

Unfortunately there is not a definitive answer to the issue about rotating chemical repellants. Common sense would dictate that it is a good idea to switch repellants if deer damage is noticed within a short time after applying a repellant.

Interspecific Competition: -- 2648

Not only is herbivory a concern, but detrimental effects of competing vegetation have been reported in the North America forestry literature over a long period. Many different methods of control have been attended throughout time and place. Techniques have ranged from physical (plowing, fire, mulching), to cultural (crop rotation, living mulches), biological, and chemical control (herbicides). Some are not as effective because of constraints on time, money, labor, or local regulations. Some techniques work better in some sites compared to others, but an optimum situation would encompass more than one method of suppression.

In reforestation, experimental designs using the combinations of fertilizer, herbicides, and mulches to reduce competing vegetation have been successful with growth and survival rates (Francis 1977, Inouye et. al. 1994, Gordon et. al. 1995, Windell & Haywood 1996). Many environmental factors on a planting site affect seedling establishment. These include inadequate or too much extremes, inadequate moisture, temperature light, and mechanical damage. Mulches lessen the negative effects of these environmental factors of seedling development. Mulches also can suppress the surrounding vegetation. Mulch can include natural material such as straw, paper, or leaf material or it can be synthetic such as plastics and cloths. Many commercial mulches are available in mat form for convenient handling and installation in reforestation. Because mulches should be in use for a few growing seasons (until seedlings root system becomes established), mulches that differ in degradability may fit specific situations better than others.

Natural material may have to be replaced, depending on the site and conditions (Windell & Haywood 1996), while synthetic mulch must be staked down and eventually removed. Mulch mats that are staked may also be a problem for use in high populations of deer, since they may knock off stakes and get their hooves tangled in sears or on edges. Manufactured mats provide the benefits of natural mulch, and also allow controlled released fertilizers, animal repellents, and herbicides that are selectively incorporated into the matting. The use of chemicals and mulching material based on silvicultural procedures ensure seedling survival and early development on sites where nutritional deficiencies, animal damage, and weed problems are expected to be severe (Windell & Haywood 1996). Although there have been reports of animals burrowing in mulch and using it for cover while feeding on tree stems and roots, damage can be minimized by reducing the depth of the mulch (<3"), and by not allowing it to accumulate against the stem of the tree. A table summarizing the characteristics of mulch materials primarily used in

California and Oregon is included at the end of this report (Technical Service Report #P.S.W.-123, U.S. Forest Service, 1990).

Herbicides:

Herbicides allow the control of weeds where tillage may not be possible or desirable. Herbicides reduce the need for money and use less labor when compared to more conventional methods, and are more effective. Herbicides can be more efficient in areas where weeds have been allowed to constitute a large percentage of land, as abandoned agricultural fields and clear cut forest where trees may have a hard time becoming established. But because of the pressures to reduce herbicides for environmental reasons, an initial use of herbicides followed by another method, such as mulching, is recommended (Windell & Haywood 1996).

Use of herbicide in controlling competing vegetation has generally resulted in an increase in tree diameter and height. Also, tree growth rates increase with soil nitrogen and drought stress may be reduced where soil organic matter is higher (Inouyle et. al. 1994). Excessive herbaceous removal has resulted in a reduced stem height, due to the exposure to deer and decrease food available to deer (Gordon et. al. 1995, Shea & Stange 1998). De Steven (1991b) also hand-weeded several plots and found that browsing occurred only on the weeded plots, the absence of vegetation allowed the seedlings to grow enough to be more noticeable to the deer. Strange and Shea (1998) also reported similar results where seedlings grown with fabric mats to reduce vegetative competition also increased the frequency of browsing.

Recommendation:

Unfortunately there are no previous studies that provide a "blueprint" for the growing conditions that will be encountered on various sites at Fernald. The literature is fairly straight forward regarding one point - deer may cause a lot of damage and death of young trees. The overbrowsing should be prevented in areas that are being planted for 3-5 years until the apical meristems of the trees are above the "browse line" (around 4 feet). Fencing is the most effective method and temporary fencing should be considered whenever possible. Tree tubes are effective for seedlings, but can not be left on indefinitely. The time period between the removal of the tubes and the trees reaching heights that exceed the "browse line" will be crucial. Chemical repellents should be relied upon heavily during this transition period.
Unfortunately, there are no scientific studies comparing the effectiveness of commercially available deer repellants on hardwoods. Information from several companies was reviewed, but none of the studies

were performed under controlled experimental conditions. Therefore, the use of the deer repellants is going to have to be by "trial and error." However, it is clear that the repellants need to be applied during seasons when browsing pressures are greatest (late fall, winter, early spring). It may be possible to contact park managers and other restoration projects in the Midwest to determine if they have any first-hand experience with some of the various repellants.

Competition between tree plantings and existing vegetation will be an ongoing battle. The use of mulch, hand removal, and herbicides will have to be used according to the existing site conditions. Although there are many different types of mulch, wood chips from existing stockpiles of felled trees and shrubs at Fernald are readily available. Wood chip mulch is a good choice. In addition to being able to "recycle" the wood chips, they will also provide a considerable amount of organic matter to the soil as they decompose. Organic mulches are preferable to inorganic mulches and papers.

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Table 1—*Characteristics of mulch materials used primarily in California and Oregon*

Category/material	Size	Cost	Longevity	Weeds controlled	Benefits/limitations	References
	feet	*dollars*	*years*			
ER						
.t-asphalt- -aft paper	2.5 by 2.5 to 3 by 3	164-435 per acre	<1-2	Annual and perennial herbs	Decomposes quickly; slides on slopes >50 pct; corners must be dug in on slopes; woody debris also used; anchor pins ineffective	Bradley 1962; Craig and McHenry 1988; Fritz and Rydelius 1966; Hermann 1964; Hobbs 1982; Mathews 1983; Newton 1961; Tung and others 1986
Pineapple paper						
Newspaper	approx. 2.5 by 2.5	Estimated 0.25-0.35 per seedling for materials and installation	<1 - 2	Annual and perennial herbs	May mat to ground, better than interlined kraft paper, easy to carry in planting bags	Hunt 1963 Main 1985
Roofing paper	1 by 1 3 by 3	—	5	Annual and perennial herbs	—	Fritz and Rydelius 1966
Polyethylene coated kraft	1 by 1 3 by 3	—	<1	Annual and perennial herbs	Rapid decomposition limits effectiveness to first year	Newton 1961
Hortopaper (pressed peat-moss and cardboard)	4 by 4	material cost 0.50/sheet	<2 wk to 3 yr	Annual and perennial herbs, shrubs from seed	Heavy, brittle; tears easily; palatable to deer	Craig and McHenry 1988; McHenry and others 1988
PLASTIC SHEETS						
Black polyethylene 1.25 mil to 6 mil	1.5 by 1.5 4 by 8 1.3 by 2.0	Total cost 250-400/acre for 4- by 8-ft squares	1/6-2	Annual and perennial herbs	Durability variable-usually short; ineffective on bear clover, tanoak; displaced by cattle, deer; can smother seedlings	Craig and McHenry 1988; Newton 1961; Potter 1985; Rietveld and Heidmann 1974; Sallander 1989
Clear or white polyethylene	1.5 by 1.5	—	<1	Herbs	Promotes weed growth from underneath; no effect on seedling survival	Fritz and Rydelius 1966; Rietveld and Heidmann 1974
ASTICS and RICS						
-a-Mat "E" (nonwoven needle-punched polyester felt)	4 by 4 5 by 5 6.6 by 6.6 10 by 10	0.84 material cost for 4- by 4-ft mats; 1,398 and 2,752 per ac for larger material and installation	>4	Annual and perennial herbs	Slight shrinkage; some germination, but poor development of herbs on mat surface; may-wick rain water away from seedlings unless good contact established w/soil; effective on tanoak sprouts	Craig and McHenry 1988; Harrington 1989; McDonald and others 1989
Phillips Duon	4 by 4	1.41 per sheet	<2	Herbs and shrubs	Good control; abrasive edges on "x" damage seedlings; difficult to insert hold-down pins; needs prepunched holes	Craig and McHenry 1988
Pac-Weave woven, ultra-violet stabilized polypropylene	4 by 4	1.37 ea for material, 350/ac installed	<2	Annual and perennial herbs	Good control; easy application; minimal shrinkage	Busse 1989
		0.66 ea for material, 327/ac installed and maintained for 2 yr				Craig and McHenry 1988
MISCELLANEOUS						
Petroleum-water emulsion	Covers 1.5 by 1.5	—	<1 yr	Herbs	Rapid decomposition	Heidmann and Rietveld 1974
Plastic buckets	15 gal.	2.00 ea.	—	Tanoak sprouts	Ineffective	Sallander 1989
Plywood	4 by 8	Very high	>5	Bearclover	Good control; cost, slope limitations	Tappeiner 1989
LOOSE MATERIALS						
Sawdust, bark chips, -y, sand	Covers 0.7 by 1	—	<2	Herbs	No toxicity noted from organic materials; ineffective	Fritz and Rydelius 1966
d chips	1.5 by 1.5	—	<1	Herbs	Washed away	Rietveld and Heidmann 1974
Wood and bark chips	18 acres, 2- to 7-inches thick	620/ac for disking site, spreading chips	>3	Controlled most grass and manzanita seedlings	Increased water in soil; some chlorosis of pines; pine growth not increased	Trevisan 1989

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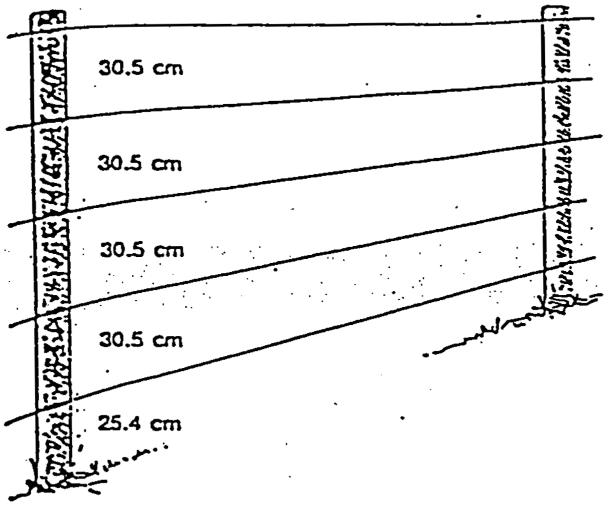
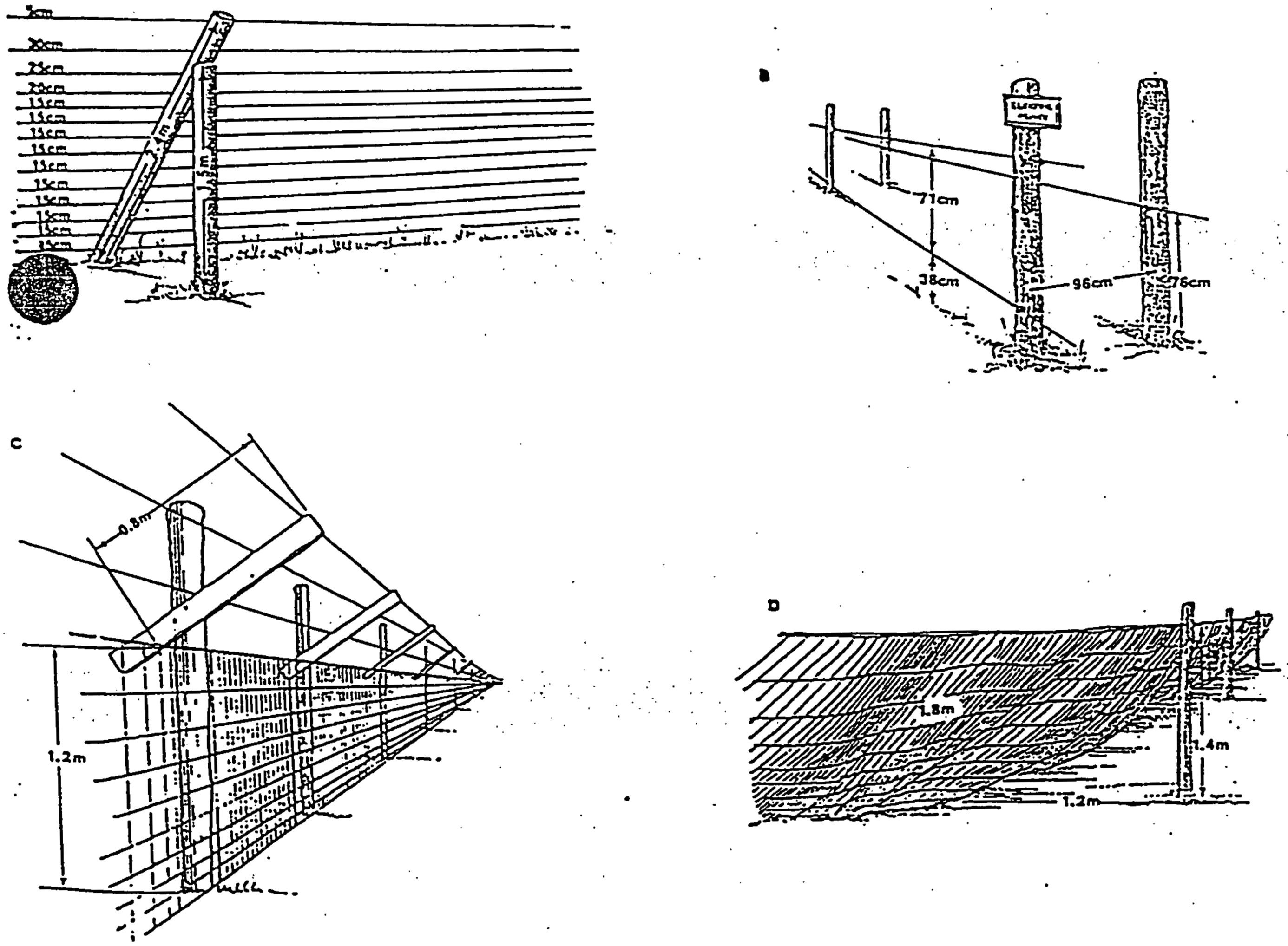


The Penn State Vertical Electric Deer Fence.



Other fence designs tested: A. Slanting, high tensile deer fence; B. Modified, New Hampshire, electric deer fence; C. Modified, stock fence; D. Slanting, or over-hanging, deer fence.

Figure 1