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Leafy Spurge Patch Expansion

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It is in the prairie climates that leafy spurge exhibits maximum vigor, to the extent of invading and competing vigorously in ungrazed, native grassland. (Selleck, Coupland, and Frankton, Leafy Spurge in Saskatchewan)

Introduction

Leafy spurge (*Euphorbia esula* L.), and its taxonomic synonyms or hybrids, is distributed on several continents possessing habitats ranging from xeric to subhumid and from subtropical to subarctic. Leafy spurge is adapted to a wide range of conditions. It is most common in moderately moist habitats (mesic) existing in the continental climate of North America (Selleck et al. 1962). From Eurasian origins, leafy spurge has spread into six Canadian provinces and 26 states of the United States (Dunn 1985). This plant has become a troublesome weed in the upper North American Great Plains where it grows largely devoid of insect and disease pests, which aid in keeping leafy spurge controlled in its native habitats (Messersmith et al. 1985).

Ecological Factors Influencing Patch Expansion

Leafy spurge is a perennial plant that grows 2 to 3 feet tall from an extensive root system. It contains a milky juice called latex, which is helpful for identification. This rapidly growing perennial is one of the first plants to emerge in the spring, giving it a competitive advantage over indigenous flora (Lym et al. 1988). Synopses on physiology, morphology, and

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[1]Research directed at finding ways to control leafy spurge has been conducted for over a decade. Current emphasis has been on biological control through natural parasites and predators of leafy spurge. This paper is the first in a series to assess the economics of controlling leafy spurge. Comments on this paper are encouraged.

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anatomy of leafy spurge have been published by Galitz and Davis (1983) and Raju (1985). Biological data on leafy spurge has been summarized by Selleck et al. (1962), Best et al. (1980), and Messersmith et al. (1985).

Autecological factors affecting leafy spurge are numerous. Leafy spurge prefers to grow on coarse-textured soils (Selleck et al. 1962), but soil texture has only a small effect on underground plant development, mainly influencing distribution of roots (Coupland and Alex 1954). Leafy spurge growing under limited light, such as the shade of a quaking aspen (*Populus tremuloides* Michx.) grove, will survive, but the percentage of flowering shoots is reduced (Selleck et al. 1962). Morrow (1979) found that leafy spurge displayed increased vigor when growing at temperatures above 13.3°C (56°F). Competition for water within a leafy spurge plant affects root bud growth (McIntyre 1979). Nitrogen supplies influence leafy spurge root development (McIntyre and Raju 1967). Small numbers of forbs growing within leafy spurge patches may indicate the plant has superior competitive or allelopathic abilities. Soil and litter collected from within leafy spurge patches will inhibit tomato growth, but isolation of phytotoxic compounds from the plant is needed for allelopathic verification (Steenhagen and Zimdahl 1979).

Leafy spurge has a mature root system framework comprised of abundant vertical and horizontal roots laden with regenerative, adventitious buds (Raju 1985). Roots as deep as 15 feet and an enormous reservoir of food stored in roots contribute to survival of the weed during unfavorable conditions (Bakke 1936). Total available root reserves of carbohydrates decline during the weed's spring growth, and then rapid carbohydrate storage is resumed in early summer, followed by a moderate rate of storage until the end of the growing season (Arny 1932). Bakke (1936) reported the age of leafy spurge roots can be estimated by rings much like the stem of a tree. The rings in leafy spurge roots are formed by a layer of starch storage parenchyma cells.

Hanson and Rudd (1933) demonstrated the ability of leafy spurge to sprout new shoots from small root segments. Messersmith et al. (1985) stated that natural dispersal of leafy spurge root fragments has not been reported, but humans transport root portions to new locations by such activities as tillage, moving landfill soil, road excavations, landscaping, transplanting sod, and transplanting nursery plants.

Leafy spurge seems to thrive with disturbance. Removal of top growth by herbicides or tillage often increases densities of the weed. Removal of 1 foot of the surface roots does not significantly affect density or vigor of plants. Removal of underground growth to a depth of 2 feet will decrease densities but will not destroy the plant. This robust perennial weed occasionally will recover and produce vegetative shoots from 3 feet of removed underground parts (Selleck et al. 1962).

Dehiscence of the leafy spurge seed capsule occurs with explosive force, throwing seeds up to 4.6 meters (15 feet) from the parent plant (Bakke 1936). Distribution of the seed is fairly uniform around the parent plants, but the wind may influence the direction of dissemination (Hanson and Rudd 1933). Less than 10 percent of the seed rain is dispersed beyond the edge of a patch (Thomas and Bowes 1976). One flowering leafy spurge stem on a native grassland will yield an average of 252 seeds (Selleck et al. 1962). Seed may remain dormant in the seed bank five years (Selleck et al. 1962), and according to Bowes and Thomas (1978a), potentially eight years.

Humans, wild and domestic animals, birds, insects, and water are agents of leafy spurge seed dissemination (Messersmith 1983). Approximately 1 percent of the seed will successfully germinate and become established as vegetative seedlings (Bowes and Thomas 1978b). Seedlings will develop vegetative buds 7 to 12 days after emergence (Selleck et al. 1962). New seedlings make up 9 to 16 percent of the stems of a stable population of leafy spurge (Bowes and Thomas 1978b).

In a native grassland habitat, it is assumed that new seedlings in a developmental stage, just outside the boundaries of an established leafy spurge patch, will be overrun by the parent's vegetative growth. Best et al. (1980) claim that patch expansion results almost entirely from lateral root spread. Each year 19 percent of the stems in a leafy spurge patch are contributed by new lateral shoot development (Bowes and Thomas 1978b). Selleck et al. (1962) commented, "Leafy spurge displays a remarkable capacity for vegetative reproduction."

Undisturbed land can have established stands of leafy spurge because the plant's root system is not disrupted as in cultivated land (Bybee 1976). Leafy spurge seedling establishment is encouraged within grassland bare areas created by livestock overgrazing (Selleck et al. 1962). Soil disturbances in mixed-grass prairie promote establishment of leafy spurge seedlings and replacement of native plant species with leafy spurge and other Eurasian invader plant species such as Kentucky bluegrass (*Poa pratensis* L.) and smooth brome (*Bromus inermis* Leyss.) (Belcher and Wilson 1989). As a result of competition within a leafy spurge patch, numerous indigenous flora species may disappear (Selleck et al. 1962). Grazed rangelands infested with leafy spurge densities of 50 percent or more will experience a decrease in annual herbage production of at least 35 percent (Lym and Kirby 1987).

Weed scientists research three types of weed control: prevention (weed species are kept from contaminating an area), control (process of limiting weed infestations), and eradication (complete elimination of all plants, plant parts, and seeds from an area) (Derscheid et al. 1985). Messersmith et al. (1985) commented, "Leafy spurge can survive in most environments and management systems, although its vegetative and reproductive development may be retarded by heavy competition or cultivation." Cultivation is more effective in reducing leafy spurge vigor than competing grass species (Coupland and Alex 1954).

Cattle partially or totally avoid leafy spurge-infested sites on rangelands (Lym and Kirby 1987). Sheep willingly graze small spurge plants and nibble on large plants (Johnston and Peake 1960). After eight years of continual sheep grazing, leafy spurge density was reduced to the growth of 5 to 10 shoots per square meter from perennial rootstocks (Bowes and Thomas 1978a). Flowering stems per square meter decreased by more than 50 percent when goats grazed in an area heavily infested with leafy spurge for 12 consecutive days (Fay et al. 1989).

According to Carlson and Littlefield (1983) and Harris et al. (1985), insect and disease organisms may be future biological control agents for leafy spurge. Chemical treatment of leafy spurge patches in rangeland, with the correct selection and application of herbicides, will increase annual forage production and reduce leafy spurge densities (Lym and Messersmith 1985). Three years of repeated hoeing of top growth before leafy spurge stems increase over 2 inches in height will exhaust the species' food reserves and eradicate the patch (Selleck et al. 1962).

Patch Expansion Model

Resource management of native grasslands, rangelands, or wildlands in the upper Great Plains requires an understanding of leafy spurge ecology. Information on spreading characteristics, area of coverage, and population densities of leafy spurge are examples of practical knowledge needed by land managers. Auld et al. (1978/1979) proposed the following conceptual weed spread function:

<u>Weed Spread Function</u> = R = f(P, I, N, E, C)

where R = rate of spread
P = dispersal pattern of propagules
I = reproductive capacity of individuals
N = population size
E = germination/establishment microsite limitations
C = climatic/edaphic limitations

A spreading plant population model, which can be used to gather management information on a typical weed invasion, is described by Auld and Coote (1980):

<u>Spreading Plant Population Model</u> = $P_n = P_1 \left[1 + \frac{c}{100}\right]^n \left[1 - \frac{s}{100}\right]^n$

where P_n = the population in year (n)
P_1 = the population in year (1)
C = constant growth rate factor
S = constant dispersing rate factor
n = year

Weed density per farm (or other unit area) can be determined with the following weed density model (Auld et al. 1978/1979):

<u>Weed Density Model</u> = $X_y = X_0 \left[\frac{(N-B)\ (1+R)}{N}\right]^y$

where X = density per farm
y = year
X_0 = original density per farm
N = initial number of farms affected
B = number of farms in each year's control program
R = annual rate of population growth

A demographic framework for examining the mechanisms that affect weed population dynamics is presented by Sagar and Mortimer (1976). Bowes and Thomas (1978b), Watson (1985), and Maxwell et al. (1988) have developed population models specifically for leafy spurge. These diagrammatic models include many environmental and physiological variables that simulate profiles of leafy spurge communities. Unless estimated coefficients and percentages, pre-calculated charts, or computers are used, many land managers do not have the resources to research and develop the required parameters for detailed population models.

The subsequent proposed mathematical formula, developed from a review of the literature, gives symbolic estimates of dynamic leafy spurge populations. The formula's foundation, based on leafy spurge research on native grasslands in the upper Great Plains, reveals contemporary or projected information on one leafy spurge seed germinating, maturing, and reproducing for (y) years into a patch covering (x) amount of land area and yielding (z) number of stems.

Leafy Spurge Patch Expansion Formula
(Metric System)

$$X = \pi*[(Y - 4)*0.61M]^2$$
$$Z = X*(100\ \text{stems}/M^2)$$

where Y = years
M = meters
X = area of patch in square meters
Z = total stems in patch

(English System-approximate conversion)

$$X = \pi*[(Y - 4)*2ft]^2$$
$$Z = X*(10\ \text{stems}/ft^2)$$

where Y = years
ft = feet
X = area of patch in square feet
Z = total stems in patch

The formula is based on the premise that more than 4 years are required before a leafy spurge seedling, growing in the competition of a native grassland, will start to spread vegetatively at an average rate. Morrow (1979) reported that a new leafy spurge seedling growing with competition will produce no more than the original shoot through the second growing season. Lateral root development of leafy spurge seedlings usually is delayed until the second or third season, especially if growing in areas with extensive vegetation (Raju et al. 1963).

The area of the leafy spurge patch is based on computing the area of a circle (πR^2), assuming that a leafy spurge patch has a circular periphery and will maintain a somewhat circular shape as it enlarges. Portions of the patch boundary may retreat some years, while other boundary areas may advance a greater-than-average distance, producing a zigzag circular periphery (Selleck et al. 1962).

The 0.61 meter or 2-foot parameter in the formula is an estimate of average annual radial spread of a leafy spurge patch. Selleck et al. (1962) found the average annual radial vegetative spread of leafy spurge patches on ungrazed native grasslands in Saskatchewan to be 0.64 meter or 2.09 feet over a seven-year period. They observed patches will continue to expand throughout the growing season under favorable moisture conditions, but the perimeter shoots may senesce if the soil becomes dry. Variations in average vegetative gains occurred in different years and habitats.

The 100 stems/m^2 or 10 stems/ft^2 is an estimate of leafy spurge stem density per unit area. An average of 59 stems/m^2 was found by Selleck et al. (1962) on three native grassland sites. After an eight-year study period, the maximum average for one site was 99 stems/m^2. Density usually did not increase over 200 stems/m^2 in most habitat situations. After a density of 100 stems/m^2 is reached, many stems appear stunted and grow no taller than three inches.

Best et al. (1980) measured stem density in a patch established on native grassland habitat in Saskatchewan and found an average of 113 stems/m^2.

Lym and Kirby (1987) categorized leafy spurge stems on rangelands into four density classes made up of zero (0 stems/m^2), low (42 stems/m^2), moderate (112 stems/m^2), and high (170 stems/m^2). The four density classes corresponded respectively to 0, 20 to 40, 40 to 60, and 60 to 80 percent leafy spurge canopy cover.

Leafy spurge patches were selectively sampled by the authors in the Sheyenne National Grasslands in North Dakota during May 1989. One hundred 0.25m^2 quadrats were sampled and revealed an average stem density of 106 stems/m^2.

Results

Patch size in any year can be estimated by using the appropriate year in the formula (Table 1). The formula recognizes a leafy spurge patch growing with native grassland plant competition but does not take into consideration the influence of management practices such as introduced plant competition, selective grazing, chemical spraying, or cultivation. The formula assumes unrestrained growth, with no interruptions from natural inhibitors (e.g., lakes and streams), cropland boundaries, other leafy spurge patches, or roadways to limit expansion.

A single leafy spurge plant, once established, will inhabit an acre in approximately 65 years based on the proposed leafy spurge patch expansion formula. A leafy spurge patch, if allowed to expand at a normal rate, will consume more additional land each year than the previous year (Figure 1). As a leafy spurge patch increases in size, the number of total stems increases proportionally to patch growth (Figure 2).

TABLE 1. ESTIMATES OF AN EXPANDING LEAFY SPURGE PATCH IN NATIVE GRASSLAND, RANGELAND, OR WILDLAND IN THE UPPER GREAT PLAINS

Year	Size of Leafy Spurge Patch			Total
	Square Meters	Acres	Hectares	Stems
1	0.01	0.00	0.00	1
5	1.2	0.00	0.00	120
6	5.0	0.00	0.00	500
7	10.0	0.00	0.00	1000
8	19.0	0.00	0.00	1900
9	29.0	0.01	0.00	2900
10	42.0	0.01	0.00	4200
11	57.0	0.01	0.01	5700
12	75.0	0.02	0.01	7500
13	95.0	0.02	0.01	9500
14	117.0	0.03	0.01	11700
15	141.0	0.03	0.01	14100
16	168.0	0.04	0.02	16800
17	198.0	0.05	0.02	19800
18	229.0	0.06	0.02	22900
19	263.0	0.06	0.03	26300
20	299.0	0.07	0.03	29900
25	515.0	0.13	0.05	51500
30	790.0	0.20	0.08	79000
35	1120.0	0.28	0.11	112000
40	1520.0	0.37	0.15	152000
45	1960.0	0.49	0.20	196000
50	2470.0	0.61	0.25	247000
55	3040.0	0.75	0.30	304000
60	3670.0	0.91	0.37	367000
65	4350.0	1.07	0.43	435000
70	5090.0	1.26	0.51	509000
75	5890.0	1.46	0.59	589000
80	6750.0	1.67	0.68	675000
85	7670.0	1.90	0.77	767000
90	8650.0	2.14	0.86	865000
95	9680.0	2.39	0.97	968000
100	10800.0	2.66	1.08	1080000

Note: Numbers rounded.

SOURCE: Leafy Spurge Patch Expansion Formula.

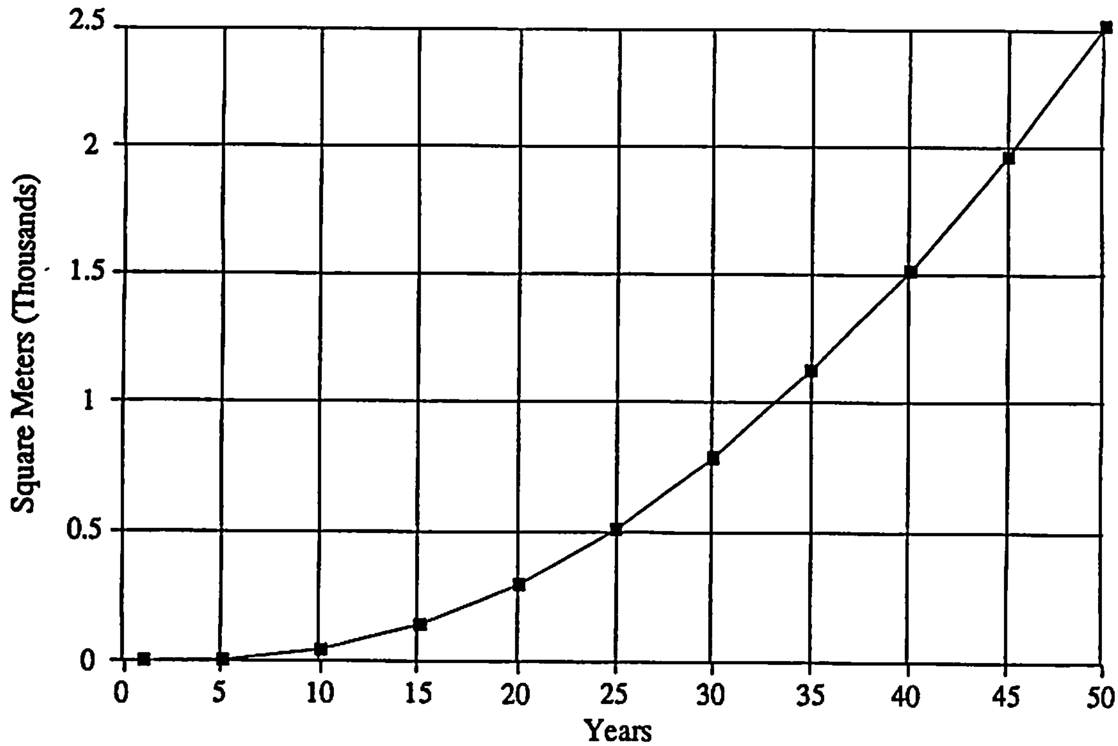

Figure 1. Leafy Spurge Patch Expansion (Square Meters).

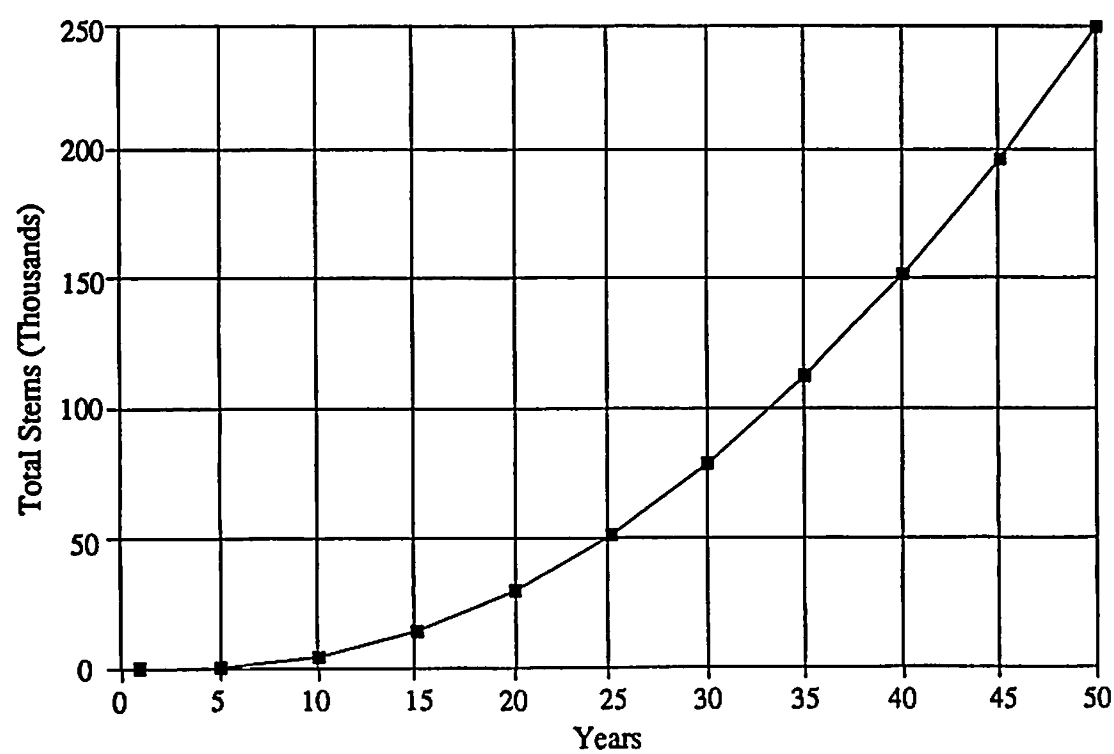

Figure 2. Leafy Spurge Patch Expansion (Number of Stems).

Selleck et al. (1962) found "Rapidity of radial growth is related to circumference rather than to area." Small patches will have a larger percentage increase in area than large patches even though the increase in radii of patches is relatively equal. This is demonstrated by the fact that a leafy spurge patch 0.5 feet in diameter will increase 500 times faster than a patch 25 feet in diameter over a five-year period, with both patches having an average 2 feet per year radial spread.

During a determined length of patch expansion time, many new, small leafy spurge patches may cover more land area than one old, large patch, with both having equal 2 feet per year radial spread. Selleck et al. (1962) explained that in five years time 2,500 patches, 0.5 feet in diameter, will cover a surface area of approximately 825,000 square feet while a single large patch, 25 feet in diameter, will attain a surface area of only approximately 1,590 square feet. The many small patches totaled together had the same surface area (491 square feet) as the one large patch at the beginning of five years (Figure 3). From a weed control perspective, this expansion response highlights the importance of seeking out and controlling small patches rather than waiting until a patch is easily identified.

The leafy spurge patch expansion formula estimates increases in patch area from established seedlings but does not generate information on new patches being formed from seed dispersal. Thus, the formula does not estimate the influence an established patch will have on creating new patches through seed mobility. Leafy spurge can infest land more rapidly if allowed to establish new small patches, providing patches expand at an average annual radial spread, than if contained to a few larger patches.

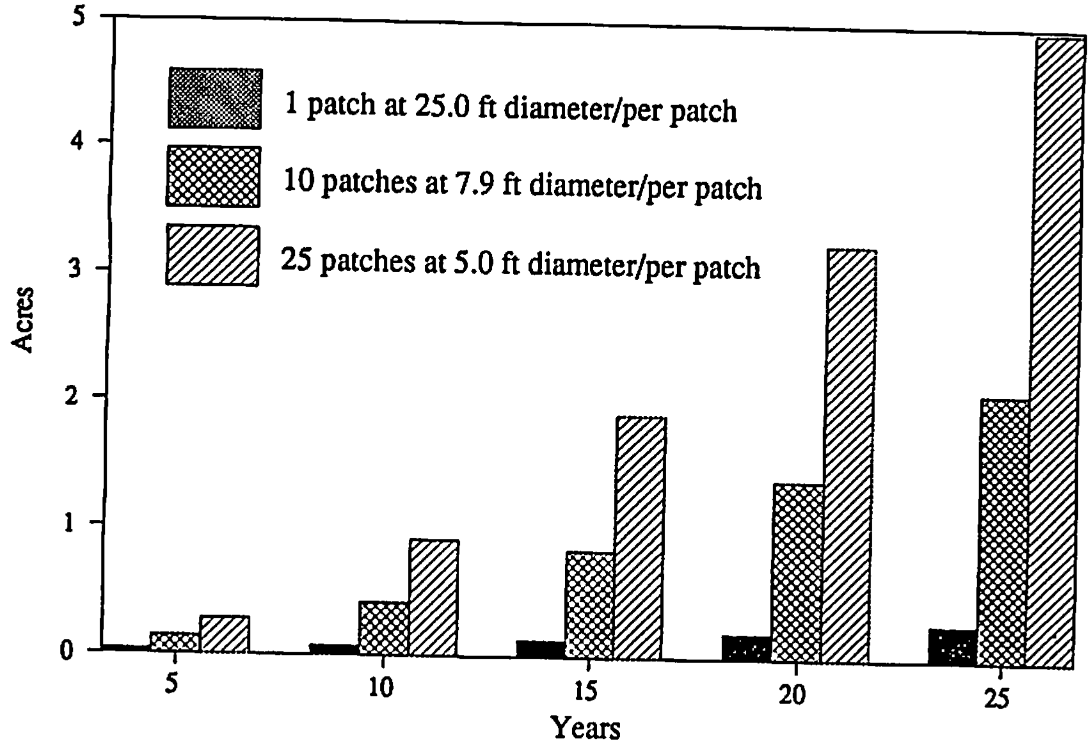

Figure 3. Leafy Spurge Infestation Over Time Given Three Scenarios. (Each Initially Equalling 491 Square Feet.) (Based on information from Selleck et al. 1962.)

Discussion

Leafy spurge patch expansion formula refinements, based on localized ecosystem surveys, may improve the formula presented. Field surveys could be undertaken on leafy spurge-infested land to determine the current number and sizes of patches before population interpretations or predictions are calculated. Other information can be extrapolated from the formula; for example, if the area of a leafy spurge patch is known, then total stems occupying the infested area or the age of the patch could be estimated. Data produced by this formula also may be used in one of the more complex weed population models.

Future research is needed to further define leafy spurge parameters. Weed spread models might be more valuable to land managers and researchers if the influence of management and environmental variables could be incorporated. Replacing or adding new variables into weed population formulas, functions, or models will enhance their usefulness. Leafy spurge patch expansion depends primarily on time, while overall infestation also depends on seed dispersal and constraints to expansion. However, in order that policies and recommendations about research directions could be made now, a simplified patch expansion model was necessary. General policy and management decisions, as well as projections of economic impacts, can be made using this simple model while natural scientists work to make it more robust.

> *A knowledge of weeds leads to the general appreciation of one's environment in the same way as the recognition of other familiar things such as birds and animals. As one learns the identity of weeds and becomes familiar with their growth habits, his perspective of life is broadened.* (Wood Powell Anderson Weed Science: Principles)

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