Field-scale spatial distribution, water use, and habitat of wild oat in the semiarid Northern Great Plains

by Lee Russell Van Wychen

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Land Resources and Environmental Sciences

Montana State University

Abstract:

Wild oat (Avena fatua L.) is widely dispersed throughout the Northern Great Plains (NGP), typically occurring in patchy distributions at the field-scale. If weeds are patchy, the environmental impact of weed control and input costs can be reduced through site-specific weed management (SSWM). However, the mechanisms regulating wild oat spatial distribution and the cost effectiveness of SSWM in the NGP need to be understood.

Field experiments were conducted to map wild oat distributions and quantify the. accuracy of continuous weed presence/absence maps produced by crop consultants for use in SSWM. The accuracy of wild oat seedling maps was 70%. SSWM of wild oat could be profitable compared to a traditional broadcast herbicide application, even with the associated technology cost and seedling map inaccuracy.

Greater increases in SSWM profitability could be realized if scouting and management efforts were directed to field areas with suitable wild oat habitat. I hypothesized that wild oat habitat may be limited by field-scale heterogeneity in plant available water. The effects of water stress on wild oat growth and fecundity was quantified in a greenhouse experiment. Lower soil matric potentials reduced wild oat relative growth rate and unit leaf rate due to an allometric tradeoff of assimilates from leaf tissue in favor of root tissue, but allowed wild oat to reproduce under adverse climatic conditions. Wild oat was estimated to produce seed above soil matric potentials of-1.66 MPa.

In three grower-managed cereal grain fields, wild oat was seeded in areas with and without historic wild oat patches to delineate field-scale habitat quality. Almost all wild oat habitat-defining variables (leaf area growth rate, harvest biomass, seeds per plant, biomass water use efficiency, and competitive ratio) were similar between existing patch and non-patch areas. Wild oat grew and produced seed regardless of existing patch boundaries and field-scale heterogeneity in soil water use. Wild oat habitat may be unlimited in agroecosystems of the NGP. Future research efforts should focus on limiting weed fecundity and dispersal instead of correlating soil properties to predict wild oat distribution.

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Lee R. Van Wychen

This dissertation has been read by each member of the dissertation committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Wild oat (*Avena fatua* L.) is widely dispersed throughout the Northern Great Plains (NGP), typically occurring in patchy distributions at the field-scale. If weeds are patchy, the environmental impact of weed control and input costs can be reduced through site-specific weed management (SSWM). However, the mechanisms regulating wild oat spatial distribution and the cost effectiveness of SSWM in the NGP need to be understood.

Field experiments were conducted to map wild oat distributions and quantify the accuracy of continuous weed presence/absence maps produced by crop consultants for use in SSWM. The accuracy of wild oat seedling maps was 70%. SSWM of wild oat could be profitable compared to a traditional broadcast herbicide application, even with the associated technology cost and seedling map inaccuracy.

Greater increases in SSWM profitability could be realized if scouting and management efforts were directed to field areas with suitable wild oat habitat. I hypothesized that wild oat habitat may be limited by field-scale heterogeneity in plant available water. The effects of water stress on wild oat growth and fecundity was quantified in a greenhouse experiment. Lower soil matric potentials reduced wild oat relative growth rate and unit leaf rate due to an allometric tradeoff of assimilates from leaf tissue in favor of root tissue, but allowed wild oat to reproduce under adverse climatic conditions. Wild oat was estimated to produce seed above soil matric potentials of −1.66 MPa.

In three grower-managed cereal grain fields, wild oat was seeded in areas with and without historic wild oat patches to delineate field-scale habitat quality. Almost all wild oat habitat-defining variables (leaf area growth rate, harvest biomass, seeds per plant, biomass water use efficiency, and competitive ratio) were similar between existing patch and non-patch areas. Wild oat grew and produced seed regardless of existing patch boundaries and field-scale heterogeneity in soil water use. Wild oat habitat may be unlimited in agroecosystems of the NGP. Future research efforts should focus on limiting weed fecundity and dispersal instead of correlating soil properties to predict wild oat distribution.

CHAPTER 1

PROLOGUE

Nothing in biology makes sense, except in the light of evolution, then, equally, very little in evolution makes sense, except in the light of ecology.

–T. H. Dobzhansky

Ecology has the distinction of being peculiarly confronted with uniqueness: millions of different species, countless billions of genetically distinct individuals, all living and interacting in a varied and ever-changing world. One of the earliest plant ecologists in America, Cowles (1901), recognized that plant succession never reaches an equilibrium state due to continuous climatic fluxes and described succession as a variable approaching a variable rather than a constant. The same can be said about weed population dynamics in agroecosystems. An agroecosystem represents a stochastic, highly disturbed, anthropomorphically manipulated system, which undoubtedly influence weed distributions within a field. The presence of weeds in crop fields and across the agricultural landscape is uncertain because seed dispersal is sufficiently probabilistic that there must always be some degree of chance involved in which a species is able to establish persistent populations (Gleason 1926, Hubbell 1995). For a specific field in a specific season, when weeds will germinate, how fast they will grow in relation to the crop, how much seed they will produce, and how effective crop growth and weed control practices are difficult to predict (Ghersa and Holt 1995). Weeds can have retrogressive and progressive phases of population growth, depending on the stochastic outcome of fecundity, dispersal, habitat, and management.

This thesis will explore the field-scale spatial distribution, habitat and water use of wild oat (*Avena fatua* L.) in dryland agroecosystems. Wild oat occurs throughout the world in cooler climates between 30 and 60° latitude (Figure 1.1) causing large economic losses in dryland cereal grain systems (Chancellor and Peters 1976). Wild oat is widely dispersed in the Northern Great Plains (NGP), but typically occurs in patchy distributions at the field-scale (Colliver et al. 1996). Entire books (Jones 1976) and symposiums (Smith 1983) have been published on wild oat, yet little research has attempted to delineate wild oat's potential habitat at any scale. Odgaard (1972) concluded that wild oat occurs widely on arable soils in temperate climates in the northern hemisphere, but Kuhnel (1965) suggested, with no elaboration, that climate-soil interactions limit wild oat incidence.

Despite the patchiness of wild oat, farmers have traditionally managed inputs according to mean field conditions. Site-specific weed management (SSWM) can reduce the environmental impact of weed control and reduce input costs if weeds are patchy. Luschei et al. (2001) estimated that if less than 72% of a field was infested with wild oat, SSWM was as profitable as a broadcast treatment to the entire field based on the assumption that the weed maps used in SSWM were 100% accurate (all wild oat were identified). However, the accuracy and future cost effectiveness of GPS-based weed maps was unknown because of the impact of wild oat escapes (field areas with wild oat that were unmapped and, thus not managed). Initial field experiments were conducted to map

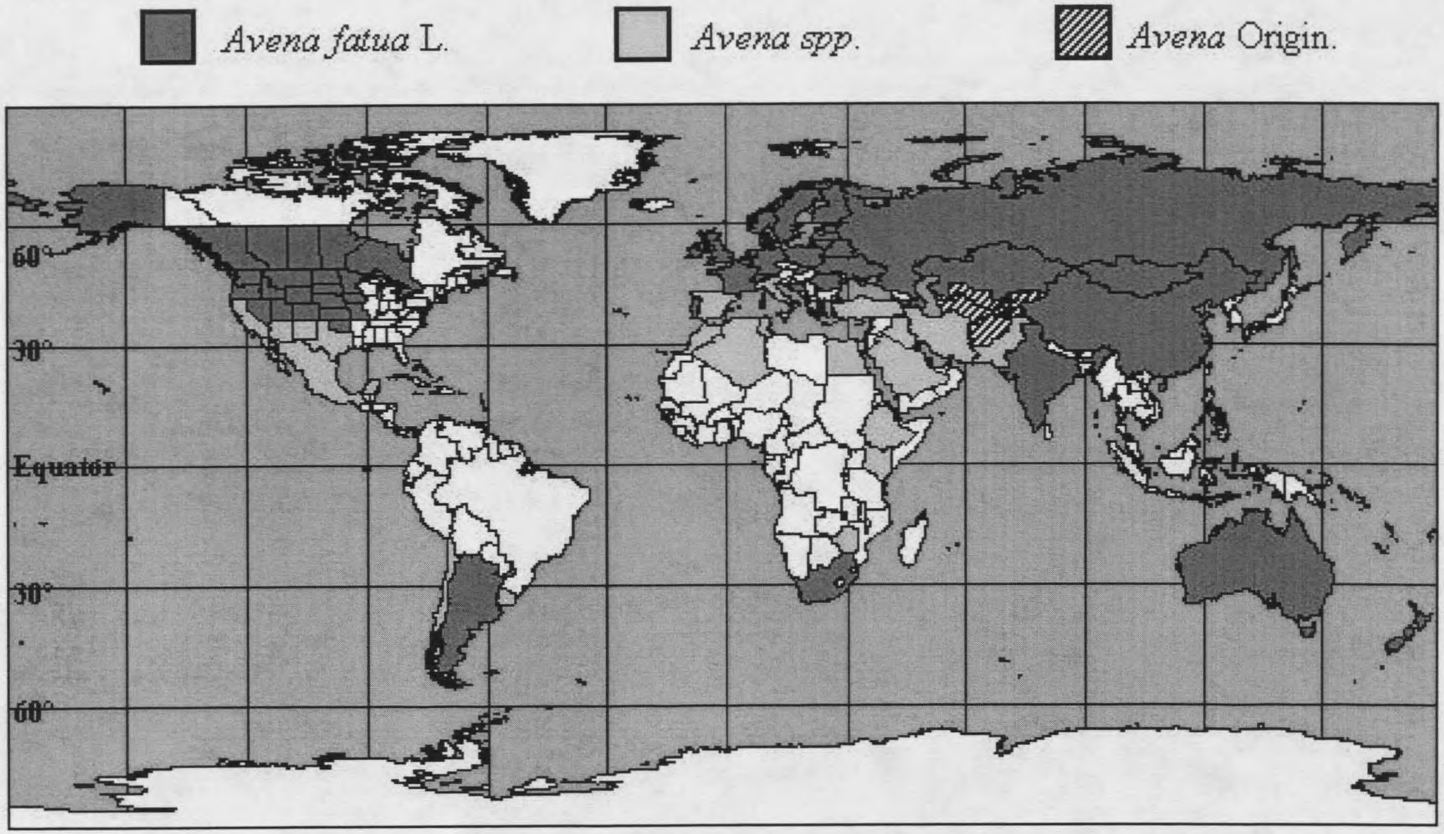

Figure 1.1. Countries, states or provinces with reported infestations of *Avena fatua* L. (spring wild oat), other *Avena* species (*A. ludoviciania, A. sterilis, A. barbata*), and the origin of *Avena* species in the Pamir (Thurston and Phillopson 1976).

wild oat distributions and quantify the accuracy of continuous weed presence/absence maps produced by crop consultants for use in SSWM.

The Cost of Weed Maps and the Information Provided

Little attention has focused on continuous weed presence/absence maps because the maps do not provide weed density information. Weed density maps of entire fields are needed for density-based threshold strategies or variable rate herbicide applications. The use of weed density maps for threshold management of weeds is a philosophically sound concept for integrated weed management, but the practical application of thresholds in the field has suffered because 1) weed density maps have been expensive to produce because of the time and labor involved (Clay et al. 1999; Wiles and Schweizer 1999), 2) farmers tend to be risk averse rather than profit maximizing (Pannell 1990; Reichelderfer 1980), and 3) the technology is still maturing for other weed identification techniques such as real-time optical sensors (Thompson et al. 1991) or remote sensing (Medlin et al. 2000). As an alternative SSWM strategy, the sprayer operator may turn the spray boom on or off during post-emergence herbicide application, thus forgoing the use of weed maps altogether. Threshold studies assume weed density is known across the field, but the cost of assessing density is typically not accounted for when calculating economic thresholds (Lindquist et al. 1999) or economic optimum thresholds (Bussan and Boerboom 2001; Cousens 1987; Munier-Jolain et al. 2002).

The cost-effectiveness and accuracy of GPS-based weed presence/absence maps may provide enough information on weed spatial distributions to support SSWM until other weed mapping technologies mature. The objectives of my first paper were to quantify the accuracy of GPS-assisted continuous sampled wild oat presence/absence maps made: 1) after crop emergence but prior to herbicide application (seedling map); and 2) during crop harvest (panicle map); and 3) to determine the economic significance of inaccuracy when the wild oat seedling map was used for SSWM.

Characterizing Weed Spatial Distributions

The economics of SSWM could be improved if we could predict weed distribution and abundance from previous weed maps. The question is raised: Why do wild oat patches occur in some areas of fields and not others? Both spatial and non-spatial techniques have been used to characterize weed distributions. Non-spatial methods such as the negative binomial (Hughes 1990); mean/variance ratio (Lloyd 1967), or Lloyd's mean crowding index (Wiles et al. 1992) cannot be used to estimate the density, location, or arrangement of weeds (Mortensen et al. 1993). Geostatistical techniques provide more quantitative information suggestive of the causative processes associated with weed spatial distributions, but a good deal of subjectivity is involved in selecting the best linear unbiased predictor for the appropriate spatial scale (Rew et al. 2001; Rew and Cousens 2001). In addition, many weed populations do not follow a normal distribution and the use of geostatictics is invalidated (cf. Rew et al. 2001). Other statistical techniques related to spatial correlation (canonical correspondence analysis, cluster analysis, principal components analysis) can provide insights into site factors associated with weed patches, but the associated factors do not imply the cause of weed distributions even though they may account for a large part of the variation explaining weed spatial distributions. Correlative techniques are dependent on the sample size and the subjective selection of independent variables.

Dale et al. (1992) conducted an extensive study correlating weed community composition in spring-seeded crops in Canada. They investigated the relationship between weed communities and variables related to crop management and soil-climatic zones in Saskatchewan (2244 fields over 4 years) and Manitoba (864 fields over 3 years). In the Saskatchewan data, there was a clear and consistent separation of the species into groups along an axis correlated with the gradient in soil-climatic zones. Kochia, Russian thistle, Persian darnel, and foxtail barley were found in the relatively warm and semiarid Brown soil-climatic zone. Common groundsel, field horsetail, common chickweed, and sheperdspurse were found in the cooler and more humid Gray Wooded soil-climatic zone. Species that occurred in high abundance throughout all five soil-climatic zones in Saskatchewan were green foxtail, wild oat, field bindweed, and field pennycress.

All of the above mentioned studies concerning weed spatial distributions are investigative techniques, but the mechanisms driving the spatial patterning of weeds cannot be discerned unless the plant population is perturbed experimentally (Harper 1977; Tilman and Kareiva 1997). In Chapter 4, we propose that the spatial distributions of annual weeds in agroecosystems are a function of fecundity, seed dispersal, management, and habitat (Figure 4.1).

Water as a Limiting Resource

Water is often the most limiting resource in agroecosystems of the Northern Great Plains (NGP) frequently resulting in terminal moisture stress (Padbury et al. 2002). The general perception among producers and researchers is that wild oat occurs mainly in field depressions that are likely to collect more moisture than surrounding areas. Based on observations during the initial wild oat mapping studies, I hypothesized that field-scale heterogeneity in plant available water may limit potential wild oat habitat in dryland agroecosystems. Few studies have quantified wild oat response to decreasing water potential (Akey and Morrison 1984; O'Donnell and Adkins 2001; Sharma et al. 1977) and none provide a complete description of vegetative growth, biomass allocation and reproductive output in response to drought stress. The goal of Chapter 3 was to quantify the impact of limiting water supply on wild oat growth and fecundity under controlled greenhouse conditions.

In the fields where I had quantified wild oat density and spatial distribution during the SSWM research, wild oat patch and non-patch areas were delineated. If lower water availability and use in non-patch areas resulted in less wild oat leaf area growth, shoot biomass and fecundity compared to existing patch areas, we could conclude that grain production fields in the NGP differ in field-scale wild oat habitat availability under the assumptions of uniform response to management and enough seed dispersal to supply seed to the entire field. Thus, proactive weed management efforts could be directed to field areas with suitable wild oat habitat, not just areas where infestations exceed an economic density threshold.

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CHAPTER 2

ACCURACY AND COST EFFECTIVENESS OF GPS-ASSISTED WILD OAT MAPPING IN SPRING CEREAL CROPS

Abstract

Managing weed infestations in a spatially precise manner requires accurate and cost-effective weed identification techniques. The goal of our research was to quantify the accuracy of continuous weed presence/absence maps and assess how management based on those maps may affect producer net returns. Each continuous sampled map covered the entire field and contained vector polygons labeled as either wild oat presence or wild oat absence. The accuracy of the continuous wild oat maps at each sampling time was determined from georeferenced quadrats of wild oat densities. The accuracy of the continuous wild oat seedling maps ranged from 48.3 to 87.1% among the six site-years. The accuracy of the wild oat seedling maps improved by at least 8% when a 10-m buffer was included around areas mapped as wild oat presence. The accuracy of continuous wild oat panicle maps from the combine at harvest ranged from 65.8 to 90.9% among the six site-years. The variation in accuracy for the wild oat seedling maps among sites was greater than the accuracy of the panicle maps. Net returns ($ ha^{-1}) for four site-years were calculated and compared for four possible weed management approaches on each field. A site-specific herbicide application to areas mapped as wild oat presence always generated higher net returns than a herbicide application over the entire field for four sites. A site-specific herbicide application to areas mapped as wild oat presence plus a surrounding 10-

m buffer area only resulted in a higher net return in one of 12 site-years compared to a site-specific herbicide application without the 10-m buffer. This site had the lowest (48.3%) wild oat seedling map accuracy and uncontrolled wild oat had a high yield impact. This research indicates that using a continuous weed sampling method based on presence or absence for site-specific herbicide application can be profitable over a herbicide application to the entire field, even with the associated technology cost and seedling map errors.

Introduction

In fields where weeds are heterogeneously distributed, site-specific weed management (SSWM) has the potential to improve producer net returns and environmental quality (Johnson et al. 1997; Oriade 1995). Many studies have demonstrated the economic benefits of SSWM over broadcast herbicide application (Felton et al. 1991; Lindquist et al. 1998; Luschei et al. 2001; Maxwell and Colliver 1995; Medlin and Shaw 2000). In addition to direct savings from reduced herbicide use, there are indirect benefits like fewer sprayer refills resulting in reduced water costs and faster application times.

An essential component of SSWM requires special technology to detect weeds at the time of management or concerns the acquisition of weed distribution information within a field. Real-time decisions require expensive equipment to recognize weed patches that construct binary spray/no-spray actions (Paice et al. 1995; Stafford and Miller 1993; Thompson et al. 1991). In the 'map-based' approach weeds are mapped in one operation and sprayed in a later field operation (Johnson et al. 1997). The map-based approach requires labor-intensive field sampling to quantify weed spatial distributions that direct spray/no-spray actions in a later operation (Clay et al. 1999; Medlin and Shaw 2000; Mortensen et al. 1993; Rew et al. 1996). The advantage of map-based weed management is the ability to manage when the weeds are not visible (i.e. preemergence herbicides).

Weed spatial distribution maps can be generated with discrete or continuous sampling techniques (Rew and Cousens 2001). Discrete sampling constructs weed spatial distribution maps by counting weed density within unique points from a predetermined grid. Wiles and Schweizer (1999) estimated the cost of collecting weed density at each point to be $0.08. They did not include the global positioning system (GPS) or data processing costs to transform the seedling counts into a weed distribution map. Intensive grid sampling of a whole field is impractical because of the time, cost and labor required (Clay et al. 1999; Medlin and Shaw 2000). Thus, construction of weed distribution maps has focused on discrete weed-sampling techniques in conjunction with spatial statistics (Cardina et al. 1995; Colbach et al. 2000; Rew and Cousens 2001). Weeds such as wild oat are heterogeneously distributed (Maxwell and Colliver 1995), suggesting that weed maps could be generated based on the spatial correlation exhibited by the species (Cardina et al. 1995; Johnson et al. 1995). However, intensive sampling is still required because large grid sizes (distances between sample points) increase the possibility of losing information due to weed spatial variation (Wiles et al. 1993).

For the continuous sampled map, data are collected over the entire area. In other words, 100% of the area is covered in vector polygons of various shapes depending on the type of qualitative description being recorded (i.e. presence/absence). Continuous sampling may be more appropriate for SSWM because it is less costly and labor intensive. Continuous sampling lacks the site specificity of discrete point samples and thus is less suitable for ecological studies. However, detailed weed counts are not required for SSWM if a herbicide spray-boom is to be switched on and off when weeds are present or absent. Several new methods of continuous weed mapping are now possible because GPS/geographic information system (GIS) technology is more accessible and affordable for producers and crop consultants (Stafford et al. 1996). Crop consultants have traditionally mapped weeds using hand drawn maps recorded during several visits to the field (Mortensen et al. 1998). Currently, the crop consulting business is expanding and adapting to provide the expertise necessary for producing spatially referenced weed maps (Mortensen et al. 1998). The least time consuming mapping method is marking weed presence/absence using GPS. The crop consultant can produce continuous sampled weed maps by toggling a switch to indicate weed presence or absence while driving at a moderate rate of speed (5-10 km hr^{-1}) in a predetermined swath width over fields. While this mapping method has the advantage of being efficient, it gives no indication of weed density, which may be useful for more refined weed threshold based management. Theoretically, the faster the mapping method, the less accurate it becomes. Regardless of the weed mapping method used in SSWM, there are likely tradeoffs between accuracy of the method and its cost.

Little attention has focused on continuous weed seedling map accuracy and the resulting impact on net returns. The success of GPS-assisted weed mapping for implementing SSWM will depend on the tradeoff between the accuracy of the method and the costs associated with the technology. The first two objectives of this research were to quantify the accuracy of GPS-assisted continuous sampled wild oat presence/absence maps made: 1) after crop emergence but prior to herbicide application (seedling map); and 2) during crop harvest (panicle map). The third objective was to determine the economic significance of inaccuracy when the wild oat seedling map was used for SSWM.

Materials and Methods

Two fields were mapped for weeds in 1998 and four fields in 1999. All fields were located in north central Montana, historically seeded to cereal grain, and either continuously cropped or in a crop-fallow rotation depending on environmental conditions. Relevant field information and dates for planting, wild oat mapping, spraying, and harvesting are presented in Table 2.1. All site-years were planted with spring wheat except Fife 1998, which had barley. The two sites in 1998 were planted about a week earlier than average Montana planting dates. The sites in 1999 were planted in a timely fashion except the Box Elder site, which was delayed due to several rainfalls in early and mid May. At all sites, the producer applied either 0.17 or 0.23 kg a.i. ha^{-1} of glyphosate to manage any emerged weeds prior to planting. At each site, four separate wild oat maps were created using a differential global positioning system

(DGPS). Both a continuous and discrete map was generated at the wild oat seedling and panicle stages of development.

The continuous wild oat seedling map was created using an all-terrain vehicle (ATV) mounted with a DGPS receiver and a computer[1]. Mapping occurred during the 2 to 6 leaf stage of wild oat. A crop consultant in the North Central region of Montana was hired to generate all the continuous sampled wild oat seedling maps. The two sites in 1998 were mapped using a patch perimeter method. The perimeter of each patch was determined as the outermost occurrence of wild oat seedlings. The ATV was driven around wild oat infested areas following the perceived patch edge until the area was enclosed. The four sites in 1999 were mapped with the same equipment. Instead of using the patch perimeter method, the ATV was systematically driven across the field on transects spaced 9.2 m apart. When the ATV encountered wild oat seedlings at any point within the 9.2 m transect a button on the computer would be turned on indicating wild oat presence. An analogy would be driving a 9.2 m wide sprayer back and forth across the field with the driver turning the sprayer on and off based on wild oat presence and absence. The crop consultant changed methods in order to decrease the time needed to map an equivalent area, but the cost remained the same. The differences in accuracy between the patch perimeter method used in 1998 and the swath-width method used in 1999 appeared to be negligible. Misclassifications of wild oat seedlings were equally likely to occur between the two types of continuous sampling methods (DeImna Heiken, personal communication).

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[1] Ashtech Ag Navigator, Model RDAC, Magellan Corp., 469 El Camino Real, Santa Clara, CA. 95050.

The data for the discrete sample wild oat seedling map was collected just before or shortly after herbicide application (Table 2.1) by walking parallel transects in the specified grid patterns described below. Wild oat density was counted in 0.29 m^{-2} rectangular quadrats laid perpendicular to the crop row at all sites. Each quadrat count was georeferenced with a DGPS receiver and computer[1]. The density of both wild oat and crop were recorded. The 1998 Sun River site was sampled on a 10- by 10-m grid in 1/3 of the field (100 quadrats ha^{-1}) and a 50- by 10-m grid in the remainder of the field (20 quadrats ha^{-1}). The 1998 Fife site was sampled on a repeating, stratified grid pattern of 20- by 20-m followed by a 5- by 20-m pattern (40 quadrats ha^{-1}). All sites in 1999 were sampled on a 20- by 20-m grid pattern (25 quadrats ha^{-1}).

The data for the discrete wild oat panicle maps was collected 2-4 wk before crop harvest (Table 2.1). Wild oat density was counted in 0.29 m^{-2} rectangular quadrats laid perpendicular to the crop row at all sites. Each quadrat count was georeferenced separately with a DGPS receiver and computer[1]. The density of both wild oat panicles and crop tillers were recorded. The 1998 sites were sampled on a semi-systemic grid resulting in approximately 15 quadrats ha^{-1} at Sun River and 19 quadrats ha^{-1} at Fife. All sites in 1999 were sampled on a 20- by 20-m grid pattern (25 quadrats ha^{-1}).

The continuous wild oat panicle maps were generated from a combine during harvest at each site. This was accomplished by using a DGPS receiver and computer[1] to 'tag' wild oat location as the 9.2 m combine header entered and exited patches. The wild oat entering the header was rated into one of four abundance categories and separated later into presence or absence classifications.

Table 2.1. Agronomic information and GPS-assisted wild oat mapping dates for six experimental site-years in North Central Montana.

Year	Site	Field size	Row spacing	Planting	Discrete seedling map	Continuous seedling map	Herbicide application	Discrete panicle map	Harvest
		ha	cm	Date					
1998	Sun River	24.3	30.5	April 22	May 28	May 18	May 29	July 26	August 18
1998	Fife	25.9	30.5	April 16	June 4	May 20	June 5	July 28	August 13
1999	Sun River	24.3	30.5	April 25	June 15	June 7	June 10	July 29	August 17
1999	Fife	25.9	30.5	May 4	June 14	June 2	June 7	July 28	August 19
1999	Box Elder	20.2	22.9	May 25	June 23	June 21	June 22	July 29	August 26
1999	Chester	12.1	30.5	May 5	June 23	June 15	June 18	July 29	August 18

Wild Oat Map Accuracy Assessment

The accuracy of the continuous sampled wild oat maps was determined at two separate sampling times; wild oat seedlings and wild oat panicles. We used the discrete sampled map with known wild oat densities to determine the continuous sampled map (wild oat presence/absence) accuracy. No comparisons were made in map accuracy between the seedling and panicle stages of wild oat. A 2 × 2 contingency table was constructed for each site at each wild oat sampling time (seedling and panicle stage). The contingency table quantified the accuracy of the continuous wild oat presence (A_{PRES}) or absence (A_{ABS}) areas relative to the discrete wild oat density samples (Figure 2.1). At each respective sampling time, we used GIS software[2] to overlay the discrete sampled map with the continuously sampled map on the same coordinate system. In this way, the data from the continuous sampled map can be ground-truthed at the exact position were the wild oat density was recorded. The combined data file was then sorted into one of four possible outcomes. These outcomes were: 1) zero wild oat m^{-2} classified as absence; 2) ≥1 wild oat m^{-2} classified as presence; 3) zero wild oat m^{-2} classified as presence; 4) ≥ 1 wild oat m^{-2} classified as absence. The first two outcomes are correct classifications and the last two outcomes are incorrect classifications. Accuracy was calculated as the number of correct classifications divided by the total number of classifications. The accuracy of the continuous sampled maps remained constant for a site whether 20, 40, 60 or 80-m grid points were used to assess the accuracy (data not shown).

Two additional methods were used to assess wild oat map accuracy. The first method used a wild oat detection threshold of ≤ 5 m^{-2} as counted in the discrete point observations. Thus, any discrete samples of wild oat ≤ 5 m^{-2} did not decrease the accuracy of continuous sample wild oat map when they were classified as absence by the crop consultant. The second method used GIS software[2] to place a 10-m buffer (A_{BUF}, Figure 2.1) around areas mapped as wild oat presence. Thus, any wild oats observed in the discrete point maps that occurred within 10-m of an area mapped as wild oat presence was counted as a correct classification.

Cost Effectiveness of Wild Oat Seedling Maps

Crop yield and net returns were predicted from the continuous wild oat seedling maps. The average wild oat seedling density for A_{PRES}, A_{ABS}, A_{BUF} and A_{OUT} (Figure 2.1) were calculated from the discrete sampled seedling maps. The Sun River 1998 and 1999 sites are omitted from analysis of crop yield and net returns due to spurious yield data acquisition. Crop yield loss was predicted from a linear yield response model for the decision scale analysis (DSA) method outlined by Luschei et al. (2000). Luschei et al. (2000) concluded that the DSA method was the best way to relate site-specific crop yield to georeferenced weed densities for these sites. The DSA method used spatial averaging to determine crop yield and a calibrated consultant map (CCM) procedure to determine weed density values. The CCM procedure combines the information from the quadrat (0.29 m^{-2}) and the continuous sampled weed presence/absence map (9.2 m width) to predict weed density at the decision scale (16-m spray boom). Crop yield loss parameter values of the intercept (expected weed-free yield) and slope (per unit yield impact of

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[2] ArcView GIS, Version 3.2, Environmental Systems Research Institute, Inc., 380 New York St., Redlands, CA. 992373