MONTANA STATE UNIVERSITY | MONTANA AGRICULTURAL EXPERIMENT STATION

MONTANA STATE UNIVERSITY | EXTENSION

Report for the Montana Noxious Weed Management Advisory Council

JUNE 2022

Photo: Shantell Frame-Martin, MNWEC (Montana Noxious Weed Education Campaign)

Montana State University
Montana Agricultural Experiment Station and Extension

INTRODUCTION

This report for the Montana Noxious Weed Management Advisory Council was assembled in compliance with the Montana Noxious Weed Trust Fund Act and Administrative Rules which require an annual report from the Montana Agricultural Experiment Station and Montana State University Extension on current projects and future plans. This report is a compilation of major weed science research and education activities conducted by MSU over the past three years and includes highlights of funded Montana Noxious Weed Trust Fund grants as well as comprehensive reporting of all weed science research products and education funding and activities.

DEPARTMENTS INVOLVED WITH WEED RESEARCH AND EDUCATION

MONTANA AGRICULTURAL EXPERIMENT STATION

MSU EXTENSION

AGRICULTURAL ECONOMICS AND ECONOMICS
Kate Fuller, *Extension Economist*

ANIMAL AND RANGE SCIENCES
Craig Carr, *Rangeland Ecology*
Pat Hatfield, *Range Sheep Nutrition*
Jeff Mosley, *Rangeland Ecology and Management*
Bret Olson, *Targeted Grazing*
Cecil Tharp, *Pesticide Education*

LAND RESOURCES AND ENVIRONMENTAL SCIENCES
Edward Davis/Tyler Hicks, *Weed Management*
Jeff Littlefield, *Biological Control of Weeds*
Jane Mangold, *Integrated Invasive Plant Management*
Bruce Maxwell, *Agroecology*
Fabian Menalled, *Weed Ecology and Management*
Noelle Orloff, *Plant Diagnostics*
Robert Peterson, *Plant-Insect Interactions*
Lisa Rew, *Non-native Plant Ecology*
Timothy Seipel, *Plant Ecology*
Tracy Sterling, *Weed Physiology*
David Weaver, *Entomology*

MONTANA NOXIOUS WEED EDUCATION CAMPAIGN
Shantell Frame-Martin, *Coordinator*

PLANT SCIENCES AND PLANT PATHOLOGY
Mary Burrows, *Plant Pathology*
Bill Dyer, *Weed Physiology*
Barb Keith, *Weed Molecular Biology*
Matt Lavin, *Botany*
Ryan Thum, *Aquatic Plant Genetics and Ecology*

RESEARCH CENTERS
Clint Beiermann, *Cropping Systems*
Pat Carr, *Cropping Systems*
Zach Miller, *Plant Ecology*
Lovreet Shergill, *Weed Science*

MONTANA NOXIOUS WEED TRUST FUND PROJECTS 2019–2021

Project Title, PI	2019	2020	2021
Biological Control Development Projects			
Biocontrol of Russian knapweed: Host testing and agent monitoring, Jeff Littlefield	●	●	●
Continuing development of candidate agents for biological control of Russian olive, David Weaver, Sharlene Sing	●	●	●
Host screening of a new biocontrol agent for common tansy and oxeye daisy, Jeff Littlefield	●	●	●
Rearing and release of the hoary cress gall mite and screening of agents by CABI, Jeff Littlefield		●	●
Host testing of a gall wasp for the biocontrol of invasive hawkweeds, Jeff Littlefield	●	●	●
Mass rearing, release, and monitoring of the northern tamarisk leaf beetle, a biological control agent for saltcedar, David Weaver, Sharlene Sing	●	●	●
Research Projects			
Developing monitoring protocols for evaluating weed management outcomes, Lisa Rew and Jane Mangold		●	
Effect of perennial grass seeding date on revegetation outcomes in weed-infested range and pasture, Jane Mangold and Zach Miller	●		
New solutions for old problems: identifying the best available biological and chemical and control options for the integrated management of invasive toadflaxes, David Weaver, Sharlene Sing	●	●	●
Stopping a wave of invasion: controlling cheatgrass, encouraging desired vegetation, and preventing spread, Lisa Rew and Jane Mangold	●		
Ventenata in Gallatin County: Surveying, mapping, and evaluating chemical control, Jane Mangold and Lisa Rew	●		
Researching best strategies for managing baby's breath *(Gypsophila paniculata)* in hay field, waste areas, and CRP, Shelley Mills, Stone Tihista, Inga Hawbaker, Bobbie Roos, Connie Wittak, Jane Mangold	●		
Development and assessment of thistle rust *(Puccinia punctiformis)* to reduce Canada thistle *(Cirsium arvense)* in Montana's rangelands, Tim Seipel			●
Multi-scale analysis of *Ventenata* control treatments on the Crow Reservation, Jane Mangold and Scott Powell			●

Project Title, PI	2019	2020	2021
Education Projects			
Montana Noxious Weed Education Campaign, Jane Mangold and Shantell Frame-Martin	●	●	●
Local Cooperative Projects			
Upper Rock Creek Cooperative weed management area, Dan Lucas			●
Douglas CWMA, Ben Hauptman			●
Middle Fork CWMA, Ben Hauptman			●
Upper Valley CWMA, Ben Hauptman			●

FUTURE PLANS: 2022 MONTANA NOXIOUS WEED TRUST FUND GRANTS

(Recommended for FY23 funding on 10Mar2022)

BIOLOGICAL CONTROL DEVELOPMENT PROJECTS

Continued mass rearing, release, and monitoring of the northern tamarisk leaf beetle: a biological control agent for saltcedar, *David Weaver*

Continuing Development of Candidate Agents for Biological Control of Russian Olive, *David Weaver and Sharlene Sing*

Host testing of a flea weevil on Russian knapweed, *Jeffrey Littlefield*

Screening of biocontrol agents for Oxeye daisy and common tansy, *Jeffrey Littlefield*

Host testing and release of biological control agents for invasive hawkweeds, *Jeffrey Littlefield*

Biological control of invasive mustards: rearing, release and collection of gall mites and continued screening of agents by CABI, *Jeffrey Littlefield*

EDUCATION PROJECTS

Montana Noxious Weed Education Campaign (MNWEC), *Shantell Frame-Martin and Jane Mangold*

RESEARCH PROJECTS

Controlling *Ventenata* now and in the future, *Lisa Rew and Jane Mangold*

New solutions for old problems: identifying the best available biological control options for management of invasive toadflaxes, *David Weaver and Sharlene Sing*

EDUCATION IMPACTS
2019–2021

MSU EXTENSION

MSU Extension Education Promoting Healthy Plant Communities

Montana State University Extension provides education promoting healthy plant communities across all 56 counties in Montana. Efforts include group offerings like seminars, workshops and field days, and one-to-one consultations for Montanans seeking education tailored to a specific situation. As Montana experienced population growth over the past two years, MSU Extension meets the educational needs to promote healthy plant communities for a changing population. Extension education for healthy plant communities can be considered in three broad categories: cropland, non-cropland, and small acreage stewardship.

Cropland

Often healthy plant community promotion for croplands centers on reducing production impacts from competing plants or financial damage from contamination of product. Specific cropland work for Richland County in 2021 included continuing to address threats of Palmer Amaranth introduction into Montana. Education benefits of this program include increased awareness of agricultural producers of Palmer Amaranth identification, and an increase in management to scout and control all invasive species. The impact is cleaner cropping systems, less crop competition from weeds and increased crop values from reduced crop contamination.

Non-cropland

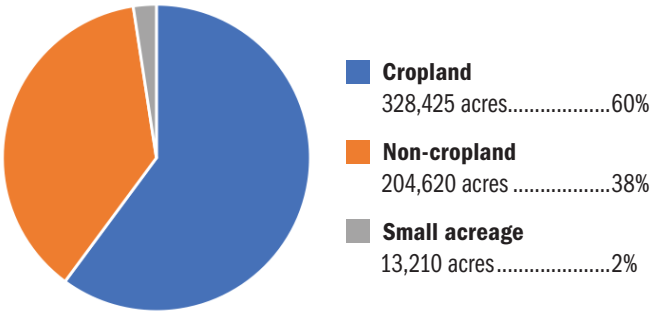
The most common non-cropland healthy plant community education for MSU Extension addresses rangelands managed for livestock production. Ben Hauptman, Granite County Extension Agent, helps rangeland stewards through a holistic approach to plant community health. His instruction includes grazing system design to promote desirable vegetation, methods to prevent invasive annual grasses from replacing spotted knapweed when it is removed from a landscape, and implementing rangeland monitoring to assure that management practices are promoting healthy plant communities.

Small Acreage Stewardship

Healthy plant community education has experienced the greatest growth among small acreage stewards, many of whom are new to Montana. Many new landowners are unaware of the requirement to control noxious weeds and are equally unaware of tools to manage a landscape for healthy plant communities. Pat McGlynn, Flathead County Extension Agent, taught Land Stewardship to a class of 176 participants. Many were new to Montana and were interested in how to manage their property without damaging the land. The class resulted in countless follow-up consultations as class participants put into practice principles learned in the class. The impact from improved plant community health on small acreages is a benefit for all of Montana.

Monitoring a spotted knapweed site in Granite County for response to management.

Weed Management Consultations (acres) 2021



MSU Extension Agents Contributing to Weed Education

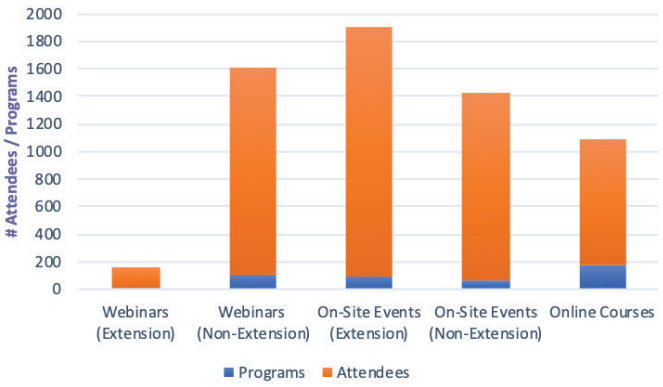
Wendy Carr, *Sanders County* · Molly Yurdana, *Gallatin County* · Wendy Becker, *Roosevelt County* · Danielle Harper, *Wibaux County* · Dave Brink, *Mineral County* · Sarah Bock, *Fergus County* · Marley Manoukian, *Richland County* · Kati Purkett, *Hill County* · Katie Hatlelid, *Judith Basin County* · Vacant, *Rosebud and Treasure Counties* · Jaycee Searer, *Dawson County* · Marc King, *Sweet Grass County* · Allison Kosto, *Broadwater County* · Ben Hauptman, *Granite County* · Pat McGlynn, *Flathead County* · Rose Malisani, *Cascade County* · Marko Manoukian, *Phillips County* · Jerry Marks, *Missoula County* · Kimberly Richardson, *Ravalli County* · Jack Bazemore, *Sheridan County* · Adriane Good, *Pondera County* · Cody Ream, *Fergus County* · Eric Miller, *Garfield*

County · Shelley Mills, *Valley County* · Ken Nelson, *McCone County* · Kim Woodring, *Toole County* · Robert Walker, *Powell County* · Inga Hawbaker, *Daniels County* · Mary Rumph, *Powder River County* · Sharla Sackman, *Prairie County* · Mat Walter, *Lewis and Clark County* · Mike Schuldt, *Custer County* · Jennifer Solf, *Musselshell and Golden Valley Counties* · Vacant, *Teton County* · Trestin Benson-Feagler, *Dawson County* · Jack Stivers, Lake County · Jessica Murray, *Beaverhead County* · Amanda Williams, *Fallon and Carter Counties* · Kaleena Miller, *Madison and Jefferson Counties* · Verna Billadeaux, *Blackfeet Reservation* · Nikki Bailey, *Carbon County* · Tyler Lane, *Chouteau County* · Kayleen Kidwell, *Deer Lodge County* · Elizabeth Werk, *Fort Belknap Reservation* · Kari Lewis, *Glacier County* · Jesse Fulbright, *Liberty County* · Makayla Paul, *Meagher County* · Josh Bilbao, *Park County* · Lee Schmelzer, *Stillwater County* · Mandie Reed, *Wheatland County*

The MSU Extension Pesticide Education Program in 2021

The MSU Extension Pesticide Education Program (PEP) serves as a hub for the certification and training of 5,200 private (farm) pesticide applicators. This program integrates 56 MSU county and tribal agents appointed as local Private Pesticide Training (PAT) coordinators, one statewide MSU Pesticide Education Specialist, and multiple MSU Extension faculty to deliver information on weeds, insects, rodents, plant diseases, and a variety of pesticide core topics (i.e. pesticide safety, calibration and pesticide fate).

During 2021 there were a total of 276 in-state, "live" sponsored private applicator events. This consisted of 124 live webinars and 152 on-site events, with a total of 101 MSU Extension and 175 non-MSU sponsored events approved to deliver private applicator information to 4,831 attendees. Most of the in-state sponsored events are at least supported by MSU Extension guest speakers. An additional 177 online modules/courses (non-live) were offered for private applicator credits. By offering these in-state "live" MSU Extension credit opportunities, thousands of private applicators retain access to highly effective chemistries, thus saving the agricultural industry millions of dollars through proper management of pests.



MAES RESEARCHERS AND EXTENSION SPECIALISTS CONTRIBUTING TO EDUCATION AND OUTREACH

Off-Campus and Remote MSU Weed Education Programs

Weed-related programs delivered (2021)..... 199

Individuals reached (2021) 9,143

Undergraduate and Graduate Level Courses

AGSC 401: Integrated Pest Management
AGSC 454: Agrostology
BIOO 435: Plant Systematics
ENSC 443/LRES 543: Weed Ecology and Management
ENSC 410/LRES 510: Biodiversity Survey and Monitoring Methods
LRES 540: The Ecology of Plants and Plant Communities
LRES 569: Ecology of Invasive Plants in the Greater Yellowstone Ecosystem
NRSM 102: Montana Range Plants
NRSM 350: Vegetation of Western Wildlands
NRSM 351: Biomes of Western Wildlands
NRSM 353: Grazing Ecology and Management
NRSM 453: Habitat Inventory and Analysis
PSPP 546: Herbicide Mode of Action

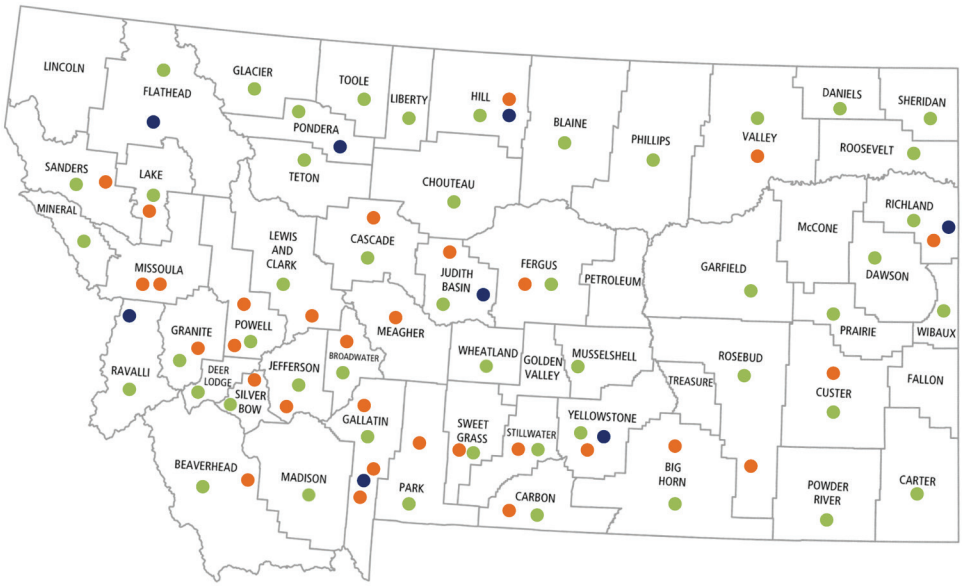
Noxious Weed Manager Training

Noxious Weed Management Certification Program: Levels 1 through 3, one level offered annually.

MSU Schutter Diagnostic Lab Weed Activities

Weed samples identified (2021) 376
Programs delivered (2021)..... 18
Individuals reached (2021) 1,100
Montana counties sending in samples (2021)..... 48

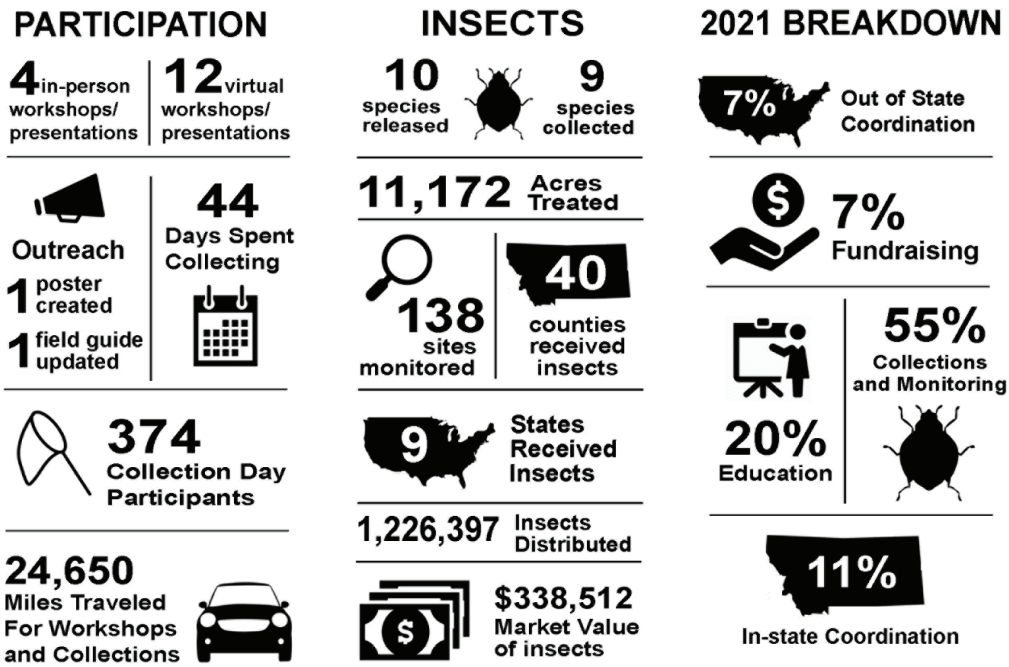
- MSU MAES Research Centers
- Off-campus MSU weed education locations (2021)
- Counties which submitted plant sample(s) to MSU Schutter Diagnostic Lab (2021)



Montana Biocontrol Coordination Project

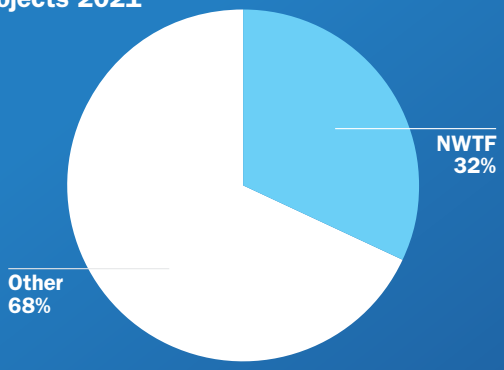
The Montana Biocontrol Coordination Project works to provide the leadership, coordination, and education necessary to enable land managers across Montana to successfully incorporate biological weed control into their noxious weed management programs. This is a soft-funded project with over 50 annual, individual contributors.

Contact Melissa Maggio, Project Coordinator,
mmaggio@missoulaeduplace.org



MSU WEED PROJECT FUNDING
2019–2021

New Grant Sources for Weed Projects 2021



2021 New Awards
Noxious Weed Trust Fund $297,442 ..... 32%
Other Sources $617,826 ..... 68%

2020 New Awards
Noxious Weed Trust Fund $289,383 ..... 13%
Other Sources $1,855,066 ..... 87%

2019 New Awards
Noxious Weed Trust Fund $351,151 ..... 41%
Other Sources $501,802 ..... 59%

OTHER FUNDING SOURCES FOR WEED RESEARCH AND EDUCATION, 2019–2021

National

U.S. DEPARTMENT OF AGRICULTURE
Animal and Plant Health Inspection Service · Forest Service · National Institute of Food & Agriculture · Western SARE

U.S. DEPARTMENT OF DEFENSE
Army Research Office

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Indian Affairs · Bureau of Land Management · U.S. Fish and Wildlife Service · National Park Service

INDUSTRY
Aquatic Plant Management Society · Bayer CropScience · Crop Life America · Dow AgroSciences

Regional
Western Sugar Cooperative · Western Sustainable Agriculture Research and Education Program · USA Dry Pea and Lentil Council

State
Bair Ranch Foundation · Central Michigan University · Colorado State University · Confederated Salish and Kootenai Tribes (MT) · Michigan Department of Natural Resources · Midwest Aquatic Plant Management Society · Minnehaha Creek Watershed District (MN) · Missoula County Weed District · Montana Department of Agriculture · Montana Department of Natural Resources and Conservation · Montana Fertilizer Advisory Committee · Montana Research and Economic Development Initiative · Montana Weed Control Association · Montana Wheat and Barley Committee · Organic Advisory and Education Council · South Dakota State University · Wisconsin Department of Natural Resources · University of Illinois

COLLABORATORS

Agriculture and Agri-Foods Canada
BBCA Rome (Biotechnology and Biological Control Agency)
CABI Europe (Centre for Agriculture and Bioscience International)
Colorado Department of Agriculture
Montana Department of Agriculture
Montana Department of Environmental Quality
Montana Fish Wildlife and Parks
Montana Weed Districts
Nez Perce Biocontrol Center
Private landowners
Task Force/Consortium Groups
University of Idaho
USDA Agricultural Research Service
USDA Animal and Plant Health Inspection Service
USDA ARS European Biological Control Lab
USDA Forest Service
USDA National Institute of Food and Agriculture
USDA NRCS (Natural Resources Conservation Service)
USDI Bureau of Land Management

TARGET WEEDS

Canada thistle *(Cirsium arvense)*
Cheatgrass *(Bromus tectorum)*
Crested wheatgrass *(Agropyron cristatum)*
Common tansy *(Tanacetum vulgare)*
Dalmatian toadflax *(Linaria dalmatica)*
Desert alyssum *(Alyssum desertorum)*
Douglas fir *(Pseudotsuga menziesii)*
Eurasian watermilfoil *(Myriophyllum spicatum, M. spicatum x M. sibiricum)*

Field bindweed *(Convolvulus arvensis)*
Hoary alyssum *(Berteroa incana)*
Houndstongue *(Cynoglossum officinale)*
Japanese brome *(Bromus japonicus)*
Juniper *(Juniperus* spp.*)*
Kochia *(Kochia scoparia)*
Leafy spurge *(Euphorbia esula)*
Meadow hawkweed complex *(Hieracium caespitosum, H. praealturm, H. floridundum, and Pilosella caespitosa)*
Medusahead *(Taeniatherum caput-medusae)*
Narrowleaf hawksbeard *(Crepis tectorum)*
Orange hawkweed *(Pilosella aurantiaca)*
Oxeye daisy *(Leucanthemum vulgare)*
Palmer amaranth *(Amaranthus palmeri)*
Perennial pepperweed *(Lepidium latifolium)*
Ponderosa pine *(Pinus ponderosa)*
Rush skeletonweed *(Chondrilla juncea)*
Russian knapweed *(Rhaponticum repens)*
Russian olive *(Elaeagnus angustifolia)*
Saltcedar *(Tamarix* spp.*)*
Smooth brome *(Bromus inermis)*
Spotted knapweed *(Centaurea stoebe)*
St. Johnswort *(Hypericum perforatum)*
Sulfur cinquefoil *(Potentilla recta)*
Tall buttercup *(Ranunculus acris)*
Tansy ragwort *(Jacobaea vulgaris)*
Ventenata *(Ventenata dubia)*
Waterhemp *(Amaranthus tuberculatus)*
Whitetop *(Lepidium draba)*
Wild oat *(Avena fatua)*
Yellow toadflax *(Linaria vulgaris)*

RESEARCH PUBLICATIONS 2019–2021

Journal articles and invited book chapters. **Bold type** denotes MSU faculty, staff, and graduate students contributing to the work.

ECONOMICS

Adams AK, Byron R, **Maxwell B**, Higgins S, **Eggers MJ**, Byron L, **Whitlock C.** 2021. *Climate change and human health in Montana: a special report of the Montana Climate Assessment* (pp. 191). Montana State University: Montana State University, Institute on Ecosystems, Center for American Indian and Rural Health Equity, Montana Health Professionals for a Healthy Climate. https://montanaclimate.org/

Tharp C, Mangold J, Sigler W, Goosey H, Wanner K, Fuller KB, Haynes G, Jones C, Van Emon M, Grocke M. 2021. MSU Extension Drought Resources in Montana. MSU Extension AgAlert. MSU Extension | Montana State University

HERBICIDE RESISTANCE

Scherrer B, Sheppard J, Jha P, Shaw J. 2019. Hyperspectral imaging and neural networks to classify herbicide-resistant weeds. Journal of Applied Remote Sensing (SPIE), 13(4):044516.

INTEGRATED PEST MANAGEMENT

Adhikari S, Burkle L, O'Neill K, Weaver D, Delphia C, Menalled F. 2019. Dryland organic farming partially offsets negative effects of highly-simplified agricultural landscapes on forbs, bees, and bee-flower networks. Environmental Entomology, 48(4), 826-835.

Adhikari S, Burkle L, O'Neill K, Weaver D, Menalled F. 2019. Dryland organic farming increases floral resources and bee colony success in highly simplified agricultural landscapes. Agriculture, Ecosystems, and the Environment, 270, 9-18.

Adhikari S, Adhikari A, Weaver D, Bekkerman A, Menalled F. 2019. Impacts of agricultural management systems on biodiversity and ecosystem services in highly simplified landscapes. Sustainability, 11(11,3223), 1-16.

Briar SS, **Carr PM**, Miller GG, **Menalled F, Miller PR.** 2019. Current status and soil biology impacts of organic conservation tillage in the U.S. Great Plains. In C. Sarath Chandran, S. Thomas, and M.R. Unni (Ed.), Organic Farming: New Advances Towards Sustainable Agricultural Systems (pp. 11-23). New York NY: Springer International Publishing AG. eBook.

INTEGRATED PEST MANAGEMENT (cont.)

Flessner M, Mirsky S, Schwartz-Lazaro LM, Bagavathiannan MV, VanGessel MJ, **Shergill L**, Ackroyd VJ, Rubione CG. 2021. From Spreader to Predator: Killing Weed Seeds with the Combine. Crops and Soils 54:40-45.

Ishaq S, Seipel TF, Yeoman C, Menalled F. 2020. Dryland cropping systems, weed communities, and disease status modulate the effect of climate conditions on wheat soil bacterial communities. *mSphere,* 5(4).

Lacoste M, Cook S, McNee M, Gale D, Ingram J, Bellon-Maurel V, MacMillan T, Sylvester-Bradley R, Kindred D, Bramley R, Tremblay N, Longchamps L, Thompson L, Ruiz J, García FO, **Maxwell B**, Griffin T, Oberthür T, Huyghe C, Zhang W, McNamara J, Hall A. 2021. On-Farm Experimentation: transforming innovation pathways. Nature Food, 2(12). https://doi.org/10.1038/s43016-021-00424-4

Larson C, Menalled F, Lehnhoff E, **Seipel TF**. 2021. Plant community responses to integrating livestock into a reduced-till organic cropping system. Ecosphere, 12(3), e03412.

Lehnhoff E, **Rew LJ, Mangold J, Seipel TF, Ragen DL.** 2019. Integrated management of cheatgrass *(Bromus tectorum)* with sheep grazing and herbicide. Agronomy, 9(6):315.

Menalled F. 2019. Sustainable agriculture and integrated weed management. In Science Publishers (Ed.), Weed Control. Sustainability, Hazards and Risks in Cropping Systems Worldwide (pp. 3-13). Science Publishers.

Menalled U, **Seipel TF, Menalled F.** 2021. Farming system and crop rotation effects on biologically mediated plant-soil feedbacks. Renewable Agriculture and Food Systems, 36, 1-7.

Metier E, Lehnhoff E, **Mangold J, Rew LJ,** Rinella M. 2019. Control of downy *(Bromus tectorum)* and Japanese brome *(Bromus japonicus)* using glyphosate and four graminicides: effects of herbicide rate, plant size, species, and accession. Weed Technology 34(2):284-291.

Meyer-Morey J, Lavin M, Mangold J, Zabinski C, Rew LJ. 2021. Indaziflam controls nonnative *Alyssum* spp. but negatively affects native forbs in sagebrush steppe. Invasive Plant Science and Management 14(4): 253-261.

Mohammed Y, Miller Z, Hubbel K, Chen C. 2020. Variety and weed management effects on organic chickpea stand establishment and seed yield in the Northern Great Plains. Agrosyst Geosci Environ. 3(1):e20035.

Sainju U, Ragen DL, **Hatfield P.** 2020. Sheep grazing to control weeds enhances soil carbon, not nitrogen. Soil Research. https://doi.org/10.1071/SR19353

Seipel TF, Ishaq S, **Menalled F.** 2019. Agroecosystem resilience is modified by management system and climate conditions via plant soil feedbacks. Basic and Applied Ecology, 39, 1-9.

RANGELAND WEED MANAGEMENT AND RESTORATION

Bailey DW, **Mosley JC,** Estell RE, Cibils AF, Horney M, Hendrickson JR, Walker JW, Launchbaugh KL, Burritt EA. 2019. Synthesis Paper—Targeted Livestock Grazing: Prescription for Healthy Rangelands. Rangeland Ecology and Management, 72, 865-877.

Davis KTD, Caplat P, Pauchard A, **Maxwell B,** Nunez M. 2019. Simulation model suggests that fire promotes lodgepole pine *(Pinus contorta)* invasion in Patagonia. Biological Invasions, 20, 1-14.

Ehlert K, Mangold J, Menalled F, Miller Z. 2019. Seeding, herbicide, and fungicide impact on perennial grass establishment in cheatgrass infested habitats. Ecological Restoration, 37, 67-70.

Epstein K, Wood D, Roemer K, **Currey B, Duff H, Gay JD, Goemann H, Loewen S,** Milligan MC, Wendt JAF, **Brookshire EJ, McNew LB, McWethy D, Maxwell B, Stoy P, Haggerty J.** 2021. Towards an urgent yet deliberate conservation strategy: sustaining social-ecological systems in rangelands of the Northern Great Plains, Montana. Ecology and Society (26), https://doi.org/10.5751/ES-12141-260110

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Neto NG, Carr C. 2021. The source of terrain slope data is an important consideration for natural resource management: a comparison of field measured and DEM calculated slope values. Rangelands, 43(3), 111-116.

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Rinella MJ, Knudsen AD, Jacobs JS, **Mangold J.** 2020. Seeding causes long-term increases in grass forage production in invaded rangelands. Rangeland Ecology and Management, 73, 329-333.

Smart A, Harmoney K, Scasta JD, Stephenson M, Volesky J, Vermeire L, **Mosley J,** Sedivec K, Meehan M, Haigh T, Derner J, McClaran M. 2021. Critical decision dates for drought management in central and northern Great Plains rangeland. Rangeland Ecology and Management, 78, 191-200.

Wood D, Seipel TF, Irvine K, **Rew LJ,** Stoy P. 2019. Fire and development influences on sagebrush community plant groups across a climate gradient in northern Nevada. Ecosphere 10(12).

Wurster P, Maneta M, Begueria S, Coburn K, **Maxwell B,** Silverman N, **Ewing S,** Jencso K, Gardner P, Kimball J, Holden Z. 2020. Characterizing the impact of climatic anomalies on agrosystems in the northwest United States. Agricultural and Forest Meteorology, 280, 107778.

Yonk RM, **Mosley JC,** Husby PO. 2020. Native American influences on the Northern Yellowstone Range—A Reply. Rangelands, 42(3), 80-82.

WEED BIOCONTROL

Ehlert K, Thorton A, Mangold J, Menalled F, Miller Z. 2019. Temperature effects on three *Bromus tectorum* (cheatgrass, downy brome) populations inoculated with the fungal pathogen *Pyrenophora semeniperda*. Invasive Plant Science and Management, 12, 150-154.

Gaffke AM, Sing SE, Dudley TL, Bean DW, Russak JA, Mafra-Neto A, **Peterson RKD, Weaver DK.** 2019. Field demonstration of a semiochemical treatment that enhances *Diorhabda carinulata* biological control of *Tamarix* spp. Nature Scientific Reports, 9(13501), 1-9.

Gaffke AM, Sing SE, Millar JG, Dudley TL, Bean DW, **Peterson R, Weaver D.** 2020. An herbivore-induced plant volatile from saltcedar (*Tamarix* spp.) is repellent to *Diorhabda carinulata* (Coleoptera: Chrysomelidae). Environmental Entomology, 49(5), 1063-1070.

Gaffke AM, Sing SE, Dudley TL, Bean DW, Russak JA, Mafra-Neto A, **Peterson R, Weaver D.** 2020. Establishing *Diorhabda carinulata*: impact of release disturbances on pheromone emission and influence of pheromone lures on establishment. Journal of Chemical Ecology, 46(4), 378-386.

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Dagati K. 2020. Long Term Multispecies Cover Crops in Semi-Arid Montana: Soil Response and Aboveground Biomass. MS Thesis. Major Advisor: Perry Miller and Cathy Zabinski.

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Douglas J. 2019. Toward 'Hypertemporal' Remote Sensing of Plant Function: A Comparison of Phenocams and Goes NDVI Data Products. MS Professional Paper. Instructor: Paul Stoy.

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Nixon M. 2020. Pest Management Challenges and Climate Change in Water Limited Winter Wheat Agroecosystems in Southwest Montana. MS Thesis. Major Advisor: Fabian Menalled.

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IMPACT STORIES

NOXIOUS WEED VIEWS AND BEHAVIORS AFTER 25 YEARS OF EDUCATION AND OUTREACH

Photo by Montana Noxious Weed Education Campaign, Shantell Frame-Martin

Increasing the general public's knowledge of noxious weeds is believed to be an important element of successful management, and many resources have been dedicated to this end. However, measuring the impact of noxious weed education and outreach efforts is limited.

In 1994, a general population survey was conducted via telephone to evaluate Montana residents' knowledge about noxious weeds. Survey results suggested more education and outreach was needed, and the Montana Noxious Weed Education Campaign (hereafter referred to as "The Campaign") was formed. The Campaign, supported by multiple federal, state, and non-governmental partners, educates the people of Montana about the economic and environmental impacts of noxious weeds and encourages participation in management. Activities include presentations, publications, trade show booths, radio and television ads, billboards, social media, plus others. The goal of this study was to evaluate noxious weed views and behaviors of Montanans after 20+ years of education and outreach.

Methods

We implemented a mail-based survey in spring 2019 that included 29 questions on topics such as knowledge and perception of noxious weeds, engagement in a variety of outdoor activities, behaviors associated with preventing noxious weed spread, sources of information for learning about noxious weeds, and self-perception of noxious weed knowledge. Whenever possible, we asked questions similar to the 1994 telephone survey. Our survey had a response rate of 18%, with 830 responses from 4,582 valid mailing addresses. Different areas of the state were equally represented across our respondents, but respondents were generally older and represented by more males than the general adult population. Therefore, we weighted responses to ensure age and gender distributions in the data match those of the general adult population in Montana.

Results

Just under half (48%) of respondents report "little" or "no" knowledge about noxious weeds, suggesting room for improvement. However, this is a 19-point improvement since 1994 when 67% reported "little" or "no" knowledge. Two-thirds of respondents indicate noxious weeds are a "serious" or "very serious" problem and recognize a wide suite of impacts associated with noxious weeds. Most respondents (61%) identify humans as contributing "a lot" to noxious weed spread, which is different than the 1994 survey in which wind, livestock, and wildlife were common answers and about one-third of respondents provided answers that were not recognized by weed professionals as common vectors. Self-reported behaviors to prevent the spread of noxious weeds (e.g., washing vehicles and gear, using noxious weed seed-free forage, disposing of seeds stuck to clothing or pets in trash receptacles) have increased over time. A variety of information delivery methods had similar levels of effectiveness, in contrast to 1994 when TV, newspaper, and radio were identified as best. Most importantly, respondents who have seen educational materials are more likely to view noxious weeds as a serious problem and to engage in behaviors to stop their spread, suggesting noxious weed education is valuable for management overall. We conclude that future efforts should continue with multi-faceted delivery of information that is action-oriented. For more details, read the entire article by Mangold, Frame-Martin, and Raile (2021).

This project was funded by MDA grant #2018-007.

DEVELOPING A STANDARDIZED MONITORING PROTOCOL TO EVALUATE EFFECTIVENESS OF NOXIOUS WEED MANAGEMENT

Monitoring the outcome of noxious weed control and the response of the co-existing vegetation is often overlooked. However, interest in monitoring has recently increased, driven most notably by variable control and cost over the long term, along with a greater need for environmental and fiscal sustainability.

Land managers want monitoring methods that are not too cumbersome to perform and provide an improved understanding of the effectiveness of their control actions and if, consequently, their desired vegetation increases. For larger land areas with many noxious weed species, monitoring information can also be used to adapt and maximize the efficiency of integrated weed management and prioritize species.

We developed a monitoring protocol to help land managers determine the effectiveness of their management on the target noxious weed(s) and co-existing vegetation. The protocol has four levels that

range in degree of complexity for field sampling, with emphasis placed on a user's plant identification skills. Information and examples of how to perform basic statistical analysis in Excel to determine differences are included in a user-friendly manual.

The protocol includes estimating cover of vegetation in frames placed along a transect. Photo by Jane Mangold, MSU.

Development of the protocol included a thorough review of existing vegetation monitoring protocols and a summary of the strengths and weaknesses of each. We then held a series of discussions with noxious weed managers, including state and federal agencies and private landowners, to arrive at a draft protocol. The protocol requires sampling in two treatment areas: treated and reference/non-treated. Land managers with a wide range of field sampling and data analysis skills tested the protocol, and improvements were made throughout 2021. Further evaluation of the protocol will be performed on different habitats and control practices (e.g., herbicide, biocontrol), and more samples will be taken over a larger spatial extent in 2022-23. These data will be analyzed to determine if the four levels have enough statistical power to determine differences in the target noxious weed(s) and other vegetation across different management treatments.

Ultimately, the protocol will allow users to determine whether their noxious weed management practices are having the desired outcome. If management is working, monitoring provides a quantitative and defendable justification for the chosen management strategies. If management is not working, or working on some sites and not others, the approach can be altered to achieve the desired endpoint of reduced target species and increasing healthy vegetation that meets management objectives.

This project was funded by MDA grant #2020-012. Further evaluation of the protocol is supported by funds from the Bureau of Land Management. For more information contact Jane Mangold (jane.mangold@montana.edu) or Lisa Rew (lrew@montana.edu).

MSU PLANT SCIENTISTS FEATURED IN NEW YORK TIMES ARTICLE ON WEED CONTROL

From MSU News Service
August 6, 2021

BOZEMAN — Two Montana State University plant scientists were featured last week in The New York Times discussing fundamental information about herbicides and offering advice to homeowners who are considering them as part of their weed control practices.

The piece, "Herbicides: What to Know Before You Use Them," was published July 28 and focuses on "horticultural vinegar", a product available at hardware and gardening stores that can be an effective herbicide when used properly. Typical household vinegar is 5% acetic acid, but "horticultural vinegar" can be dangerous due to its high concentration of acetic acid, typically 20-30%. Some acetic acid-based products aren't marketed as an herbicide, according to Jane Mangold, a professor in the College of Agriculture's Department of Land Resources and Environmental Sciences, because they aren't registered with the Environmental Protection Agency as a pesticide.

When it comes to weed control, Mangold and Noelle Orloff, a diagnostician for MSU Extension's Schutter Diagnostic Laboratory, advocate for an integrated pest management approach that involves tailoring weed control methods to fit a given space and ecosystem, as well as the plants themselves.

"For those dealing with a very abundant invasive plant scattered over a large area, hand-pulling is impractical," said Mangold in the article. "You have to weigh the risks of using an herbicide versus doing nothing — impacts such as lower biodiversity and other ecosystem effects."

Mangold and Orloff note that many people use herbicides to control weeds without having the proper knowledge of how to use them safely. In the case of horticultural vinegar, individuals should wear eye protection as well as long sleeves and pants, socks and closed-toe shoes. Many don't realize how dangerous the substance can be to human skin, eyes and lungs without appropriate clothing and protective equipment. Orloff said home gardeners often also skip the important management step of determining whether a control method will be effective.

MSU photo by Kelly Gorham

"'I'm trying to get rid of — fill in the blank,' they tell us," she said. "And then they list all the things they have done so far to the weed, like spraying bleach on it." The New York Times piece notes that, incidentally, bleach is not a recommended herbicide for garden weeds.

A series of questions will help gardeners and homeowners educate themselves on how best to control weeds, Mangold and Orloff said. What is the plant? Is the treatment they are considering effective on that type of plant? Is the space where the weed is growing feasible for the treatment — a small garden plot versus an entire field of invasive weeds, for instance? And are the environmental conditions right for the herbicide or other control being considered?

Another key piece, said Mangold, is differentiating between noxious weeds — invasive species that can cause environmental damage and crowd out native plants — and nuisance weeds, which are generally easily pulled up and are less detrimental to native local ecology. With so many readily available herbicides, it is easy for homeowners to get overwhelmed, but those kinds of decisions are exactly the ones the MSU Extension personnel like Mangold and Orloff seek to help Montanans make.

"There are lots of different ways to manage weeds," said Mangold. "Whatever you do, do it fully informed. If you don't know, first ask for help."

MSU Extension educators also recently published a new MontGuide designed to help Montanans learn about herbicides and how to use them safely. The guide, "Herbicides: Understanding What They Are and How They Work," can be downloaded for free from the MSU Extension website. Orloff will also appear on the August 7 episode of the podcast "A Way to Garden," discussing how these ideas affect home gardeners.

MSU Extension seeks to improve the lives of Montana citizens by providing unbiased, research-based education and information that integrates research and engagement to strengthen the social, economic and environmental well-being the state's communities.

https://www.montana.edu/news/21357/msu-plant-scientists-featured-in-new-york-times-article-on-weed-control

MSU TEAM PLAYS KEY ROLE IN $4 MILLION NATIONWIDE PRECISION AGRICULTURE RESEARCH GRANT

By Reagan Colyer, MSU News Service
August 11, 2021

BOZEMAN — Researchers from Montana State University's College of Agriculture and Norm Asbjornson College of Engineering will collaborate with wheat producers around Montana to collect and analyze real-life data as part of a 15-state precision agriculture project.

The Data-Intensive Farm Management project was recently awarded a $4 million grant from the U.S. Department of Agriculture's Natural Resources Conservation Service to work with farmers across the country to improve the efficiency of planting, management and input decisions, integrating technological advancements into agricultural practices.

MSU researchers John Sheppard and Bruce Maxwell are part of a 15-state research project examining precision agriculture practices.

As part of the project, MSU professors Bruce Maxwell of the Department of Land Resources and Environmental Sciences and John Sheppard of the Gianforte School of Computing will develop a user-friendly system for on-farm experimentation, data collection and analysis, as well as a framework to help farmers make the most cost-effective and ecologically sustainable management decisions.

"We placed a focus on what we thought was most important for Montana, which was to see what information we could get from precision technologies that were becoming commonplace on the farm, including yield monitors and protein sensors," said Maxwell. "We saw this as a big opportunity to determine: Can Montana farmers increase profits by using this technology?"

Because of diverse geography and climate across Montana, variables such as fertilizer application and irrigation can be fine-tuned using modern technologies to conduct experiments in every field, with minimal extra effort by the producer. Maxwell and Sheppard had been collecting that type of data for several years through MSU's Montana Research & Economic Development Initiative, which ran from 2016 to 2017. Because of that initiative, many Montana farmers already have the tools to conduct site-specific evaluations of fertilizer, weed control and seeding rate management strategies.

Maxwell has been researching precision agriculture since 1998 and works closely with farmers around Montana to design on-farm experiments and assess crop production. He will lead the on-farm experimentation component of the DIFM project and develop tools and procedures for making field treatment prescriptions.

Paul Broyles, who farms winter wheat, malt barley and legumes in Stillwater County with his father, Gary, has worked with Maxwell for the last six years collecting data on their land.

"We feel like as farmers we've learned a lot through the experiment, just from sitting in the seat of the sprayer or the combine," Broyles said. "It's been helpful. It's been interesting to see how the changes we have made in application rates, based on our observations, have increased productivity."

Since 2015, Sheppard has explored artificially intelligent tools to design on-farm experiments and predict crop yield. He'll lead the development of an "analytical engine" that will use complex modeling

and machine learning to identify trends in years' worth of data and make recommendations based on variation across the 15 project member states — even at scales down to individual sections of a particular site.

"By introducing artificial intelligence and machine learning technologies focused specifically on farmers' needs and practices, we hope to enable farmers to make data-informed decisions tailored to their farms," said Sheppard. "While the main goal is to increase farmer profit, we also hope to help farmers make decisions to reduce negative environmental impact."

The DIFM project, led by University of Illinois agricultural economist David Bullock, is the largest of 14 grants awarded by the NRCS to help partners implement and evaluate innovative conservation practices on their farmland. The funding is provided through On-Farm Conservation Innovation Trials, a component of the Conservation Innovation Grants program first authorized in the 2018 Farm Bill. Awardees are required to evaluate the conservation and economic outcomes from the practices and systems they study, giving partners, producers and NRCS critical information to inform future conservation work.

For Maxwell and Sheppard, that also includes advising Montana farmers in methods that they can put to use.

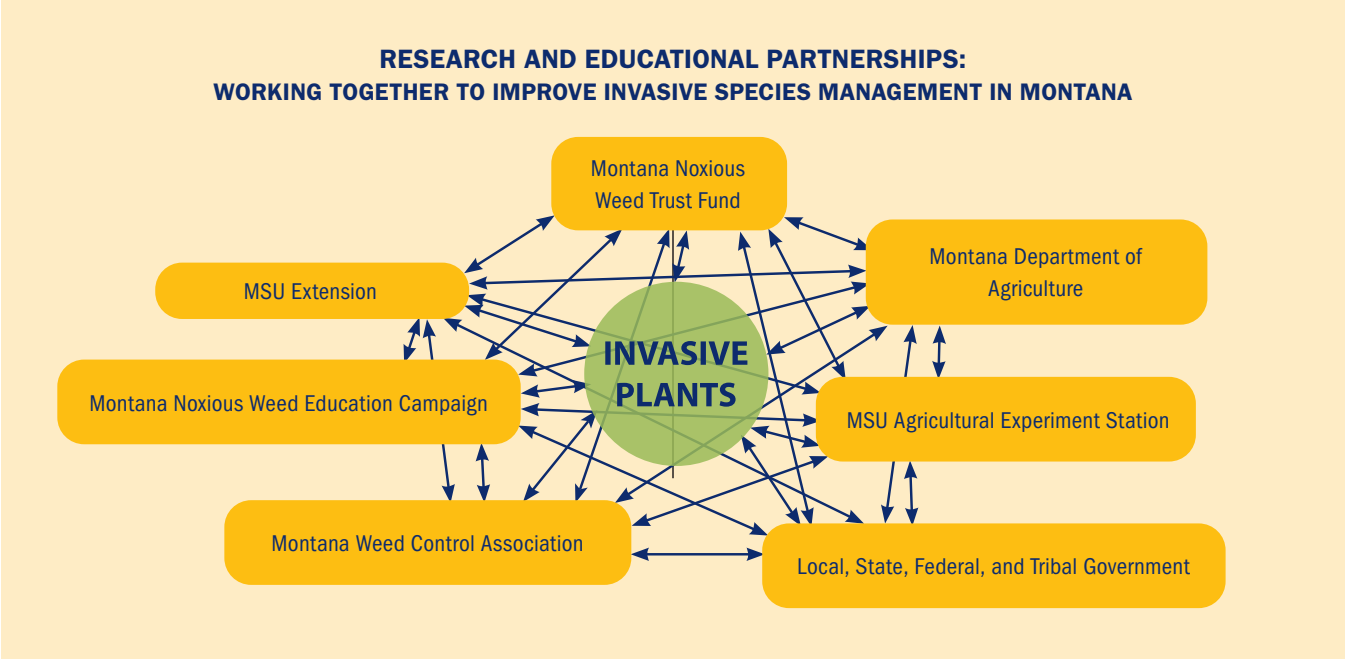
"I think most of our collaborating producers are excited about it and feel like they're getting some really good information," said Maxwell. "They're experimenting, and they like this idea of utilizing our approach to learn more in the context of their operation. Now they're expanding their experiments on their own, which is ultimately what we'd hoped for them to be able to do. It's our job to synthesize that information, put it together in a way that helps them make better decisions."

For the Broyles family, the core value of the research lies in the ability to take what Maxwell and Sheppard develop and put it into use on a daily basis.

"We had a better time producing accurate data when we learned how to do more of this in house," said Gary Broyles. "We have more confidence now. In the development of this project, we feel more confident that what we were learning is reliable."

The Data-Intensive Farm Management project is recruiting producers in Arkansas, Idaho, Illinois, Louisiana, Texas, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, South Dakota and Washington, but cotton, corn, soybean and wheat farmers from any state can apply to participate. More information can be found at the DIFM project homepage.

https://www.montana.edu/news/21367/msu-team-plays-key-role-in-4-million-nationwide-precision-agriculture-research-grant



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