Fugitive dust impacts on plants and landowner/citizen perceptions of Bakken development

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Objectives: The purpose of the project was to (1a) describe quantity and spatial extent of fugitive dust from Bakken oilfield traffic and (1b) determine if dust exposure causes physiological stress to economically-important plants. We also sought to (2a) determine landowner perceptions of energy-related impacts and (2b) identify research priorities in the Bakken.

Methods applied: (1) We collected dust and soil samples and measured plant physiology from wheat fields in the Bakken region during two growing seasons, and conducted a greenhouse experiment with several crops and perennial grasses under extreme dust load. (2) We conducted focus groups with community leaders to develop a by-mail landowner survey.

Results in a nutshell: *Biological component:* Oilfield traffic generates substantial amounts of fugitive dust and while most of it is concentrated within 30 m of roadways, non-negligible deposition rates occur up to 100-200 m into fields. However we have little evidence that dust exposure harms crop physiology and no evidence that dust exposure affects post-defoliation recovery of perennial grasses. *Sociological component:* In general, focus group participants and survey respondents alike seemed to welcome energy development on farm and rangeland in western North Dakota, and recognized potential financial gains for themselves and their communities. Both groups expressed discomfort with the speed of development during the Bakken boom and skepticism of the capacity and willingness of government to regulate the energy industry and share energy revenues with Bakken-area communities in a fair and timely manner.

Summary of products: 5 state-level poster presentations, 3 national-level poster presentations, 1 national-level oral presentation, 1 international-level oral presentation (also published in conference proceedings); minimum 4 peer-reviewed journal articles in preparation.

Acknowledgements

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Overview of accomplishments

We achieved all research objectives of the original proposal; presentation and outreach activities are ongoing as thesis and manuscript preparation continues. Research activities involved two NDSU graduate students, a group of DSU undergraduate summer interns, and two NDSU undergraduate research assistants. Research presentations were given at state, national, and international levels with additional materials in preparation.

Biological component

Field study

Research objectives

- Determine the amount and spatial extent of fugitive dust generated by oilfield traffic
- Determine if foliar deposition of fugitive dust has negative impacts on crop physiology
- Determine if chemicals associated with dust suppressants accumulate in soil

Figure 1: Jonathan Spiess with one of his dust traps in a Dunn County wheat field.

Results

Oilfield traffic produces a substantial amount of dust, even up to 100-200m from the road. We installed dust collectors in crop fields throughout the Bakken at increasing distances from unpaved roads to determine how much dust was produced, and how far this fugitive road dust traveled (Fig. 1). Although our 2016 data are still being processed, we found that while most

dust deposition occurs within 30 m of the road, a substantial amount of dust drifts out to ca. 100 m and even out to nearly 200 m (Fig. 2). The amount of dust generated is a combination of vehicle speed and size (weight and number of axles) and road surface wetness. The direction and distance of dust deposition is determined by wind speed and direction.

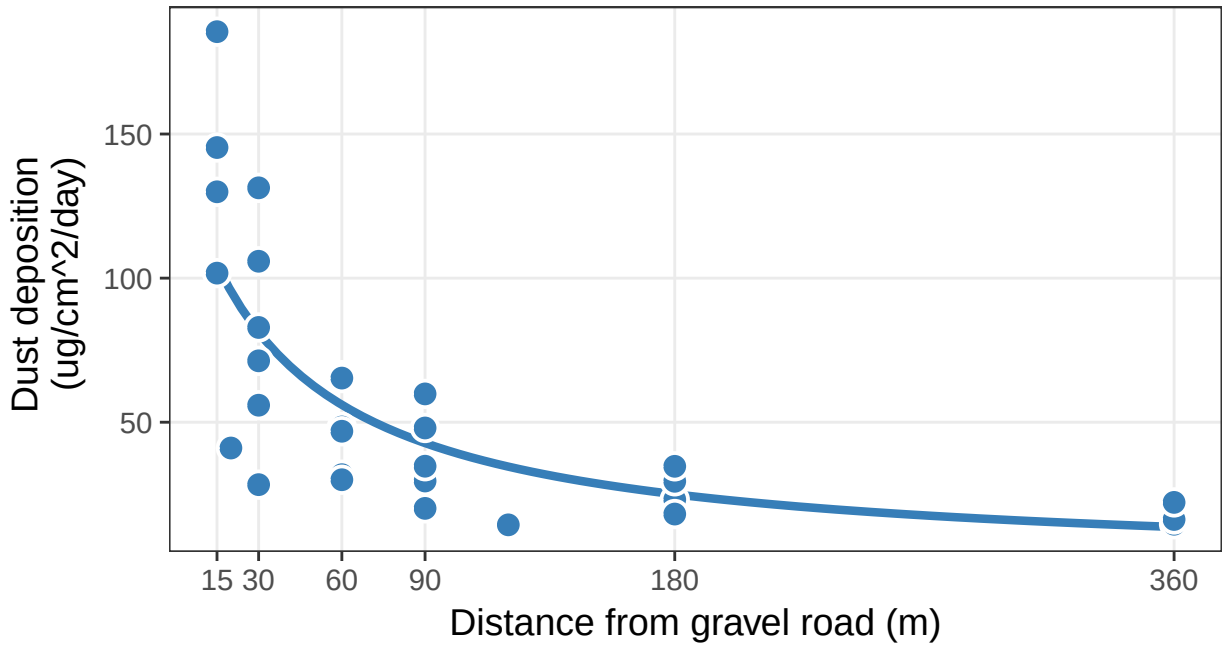

Figure 2: While fugitive dust deposition is certainly most extreme near roadways, a substantial amount of deposition often occurs up to 100-200 m from the road. These data are expressed as amount per day for 2015 (2016 data are still being processed.)

We found little evidence that foliar dust deposition affects physiology of wheat. Along transects extending nearly a quarter-mile into wheat fields, we measured three traits widely associated with plant performance and connected in the literature to dust response, specifically: photosynthetic activity, stomatal conductance, and chlorophyll content. We found little evidence for an overall effect of dust on plant physiology (Fig. 3). These data were characterized by high variability at nearly all sampled scales: plant-plant, within fields, among fields, and from year to year.

One note on these data: both 2015 and 2016 growing seasons were characterized by frequent rainfall. In our observations, precipitation causes dust to run off the surface of plant leaves. Thus, it is likely that despite high levels of dust deposition in these fields (Fig. 2), the actual dust pressure on crops was low as leaves were frequently washed clear. It is possible that in seasons with less rainfall, crops might show physiological responses to dust (although our greenhouse study on juvenile plants also show high variability under extremely high levels of dust exposure; see below).

Little evidence that dust suppressants accumulate in soil. Farmers and conservation agents reported concern over the environmental fate of chemicals applied to road surfaces as dust suppressants; after continued heavy traffic the crust formed by the application of solutions such as magnesium chloride (MgCl) breaks up, fugitive dust production resumes, and observers wonder: where did the MgCl end up? To determine if MgCl carried by dust and deposited in fields—creating a potential long-term impact with chronic impacts on crops—we collected soil samples from fields located along recently-treated roads. There is no conclusive evidence

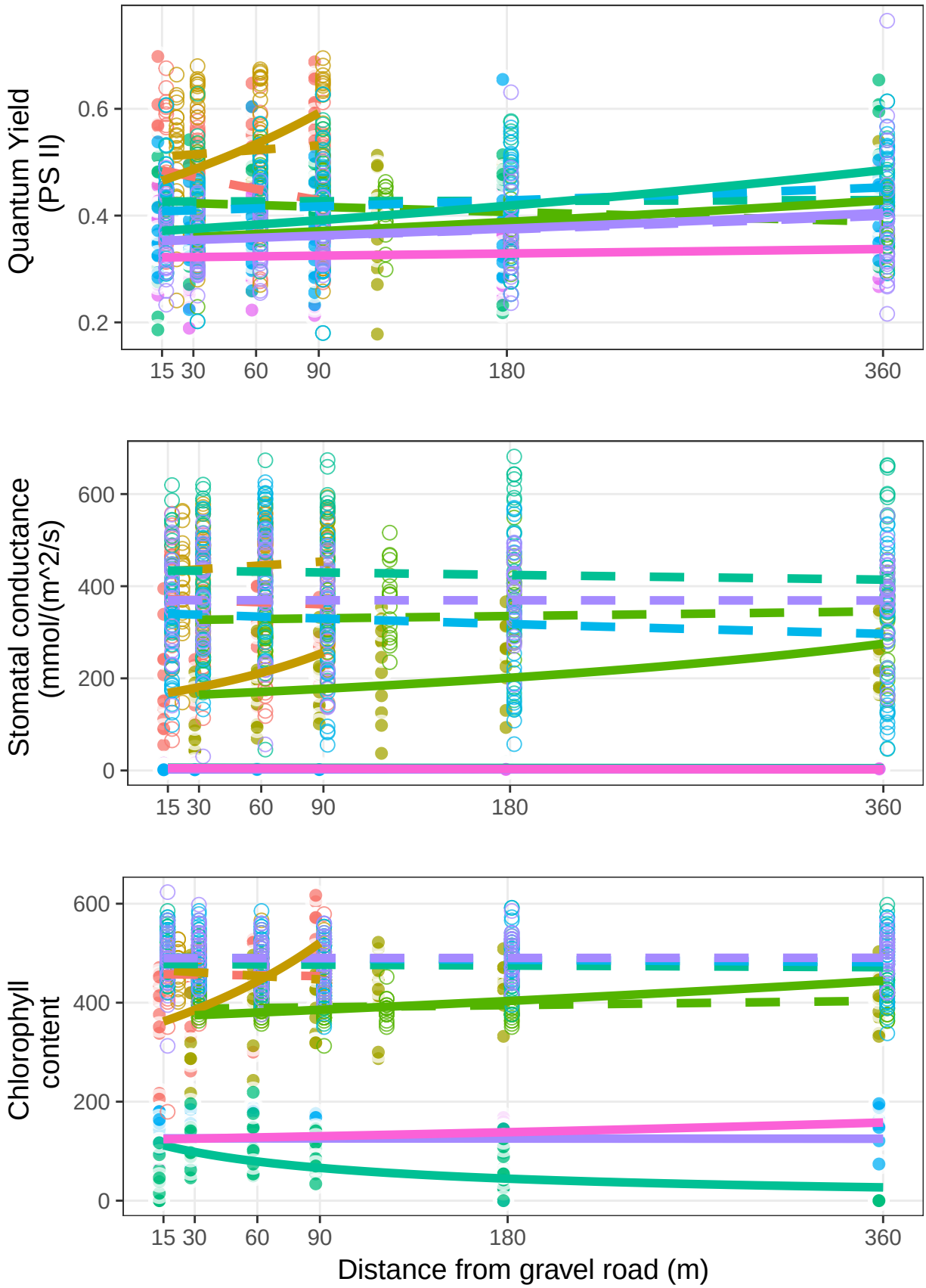

Figure 3: Physiological responses of wheat plants at increasing distances from gravel roads in the Bakken oil patch are characterized by high variability. Top: Photosynthetic efficiency (carbon fixed/photons absorbed); Center: Stomatal conductance (gas exchange rate through leaf stomata); Bottom: Colors represent individual fields. Open circles and broken lines denote 2015 data, filled circles and solid lines represent 2016 data.

to suggest MgCl accumulates in fields (Fig. 4) but trends were curious: sub-soil magnesium concentrations were greater further from roads, suggesting that if road-applied MgCl is a source, the chemical is both carried far and apparently permeates through the topsoil and collects in the subsoil. Trends in both magnesium and chloride require further exploration of their soil chemistry.

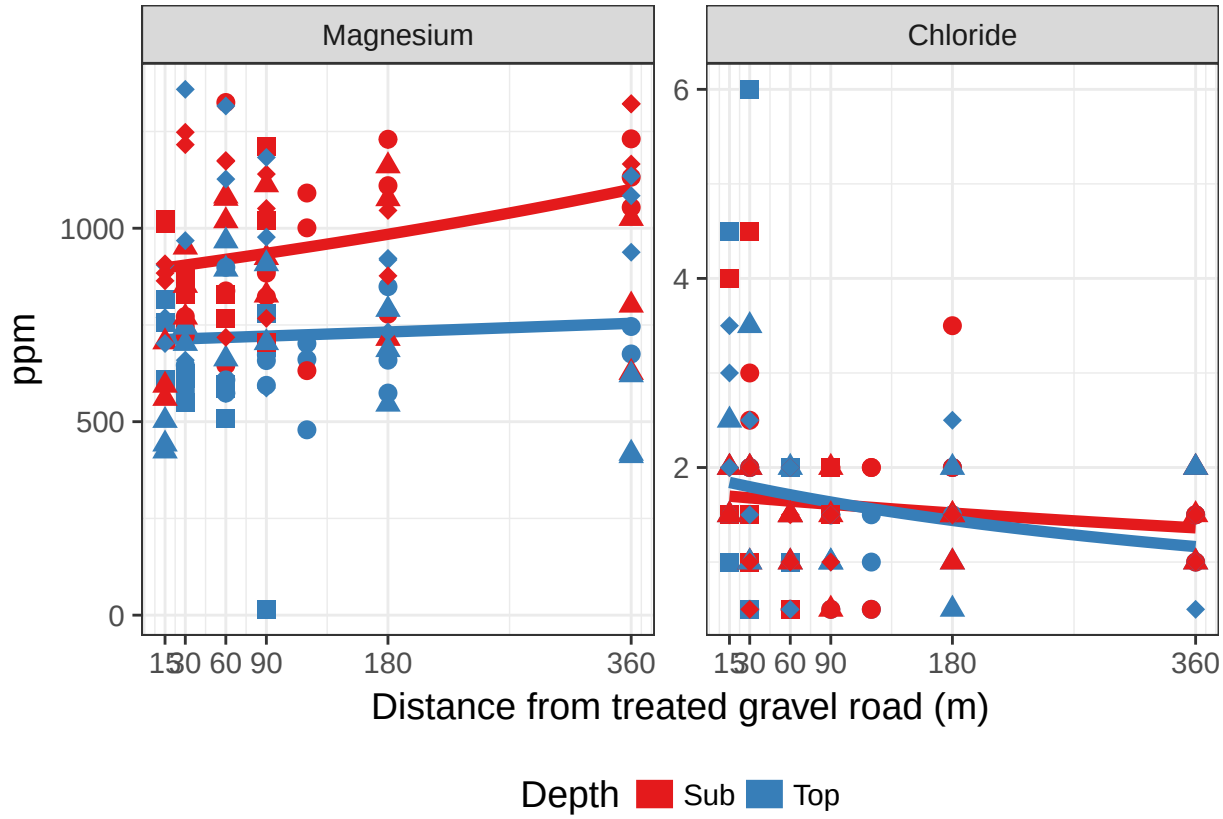

Figure 4: Magnesium and chloride concentrations in fields along gravel roads in the Bakken oil patch show divergent trends, providing little direct evidence that the magnesium chloride applied to gravel roads for fugitive dust abatement has accumulated in the soil.

Greenhouse study

Research objectives

- Determine physiological responses of plant to extremely high levels of dust exposure (field observations were limited to low foliar dust levels due to frequent rainfall)
- Test responses to dust exposure across a broad suite of crops and perennial grasses (field observations were limited to wheat)

(a) Poly tents and duster.

(b) Close-up of dust on *Bouteloua gracilis*.

Figure 5: View of experimental set-up for perennial grass response to dust in the greenhouse.

Results

Little evidence that dust exposure affects crop physiology. As in the field, we measured quantum yield, stomatal conductance, and chlorophyll content in addition to a destructive measure, specific leaf area. This experiment added two key components to the field study (Fig. 5):

- Several crops of three different types: cool-season grains (barley, durum wheat), warm-season grains (corn, sorghum), legumes (pinto beans and lentils), and sunflower.
- Extremely high dust exposure: Plants were exposed to a months' worth of road dust at a time, three times a week, for two weeks.

However, we found little evidence for consistent dust effects across plants exposed to dust and adjacent un-exposed plants (Figs. 6 & 7).

No evidence of dust impact on perennial grass recovery from defoliation. To test the response of several economically-important perennial grasses to dust, we clipped long-established, potted grasses and compared the amount of biomass recovery across groups of plants exposed and not exposed to dust. The clipping treatment was repeated to test for an effect of dust and additional stress from defoliation, but we found no differences between species or clipping events across dust exposure levels (Fig. 8).

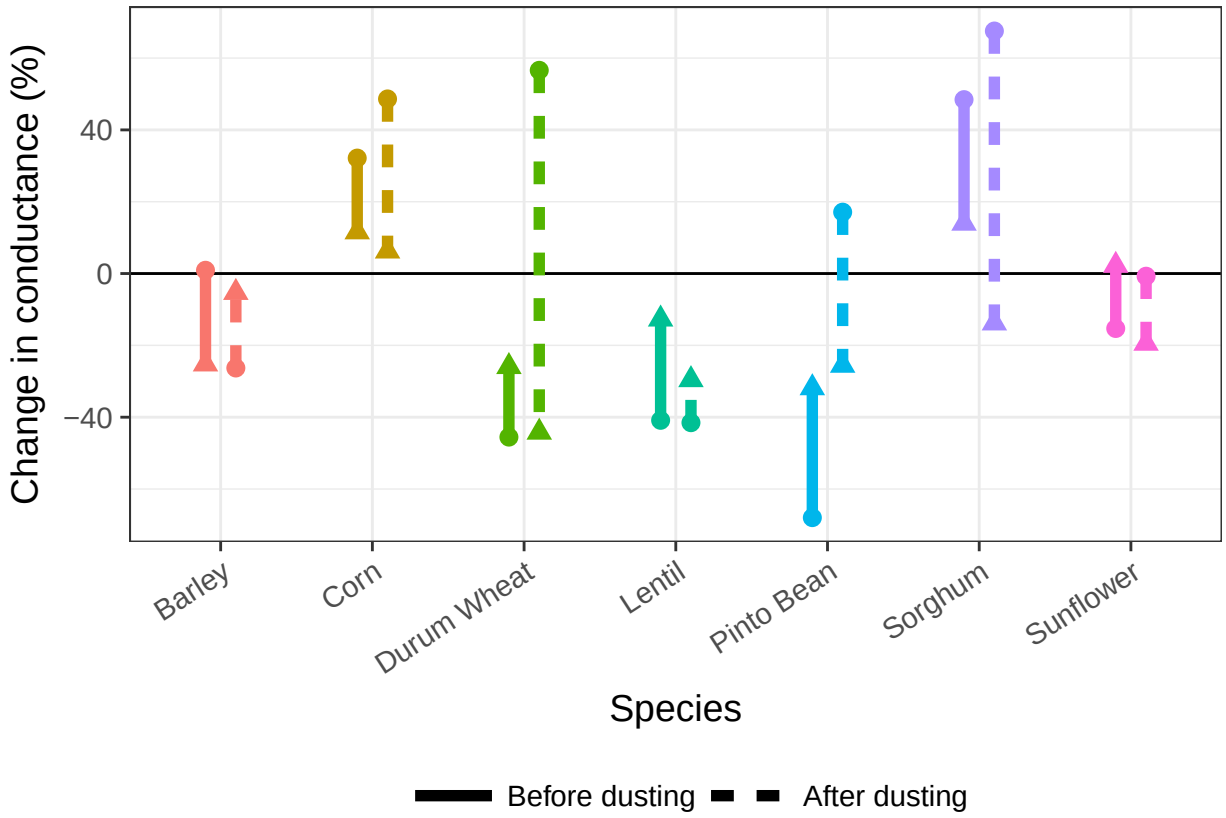

Figure 6: No evidence of a consistent effect of dust on stomatal conductance, reported here as percent difference among plants exposed to dust versus unexposed controls. Measurements were taken from exposed plants immediately before dust exposure (solid lines) and immediately after (broken lines); differences in side-by-side comparison of line types suggest no immediate effect of dust. Lines connect two replicated blocks of eight individual plants each; line length characterizes variability in response.

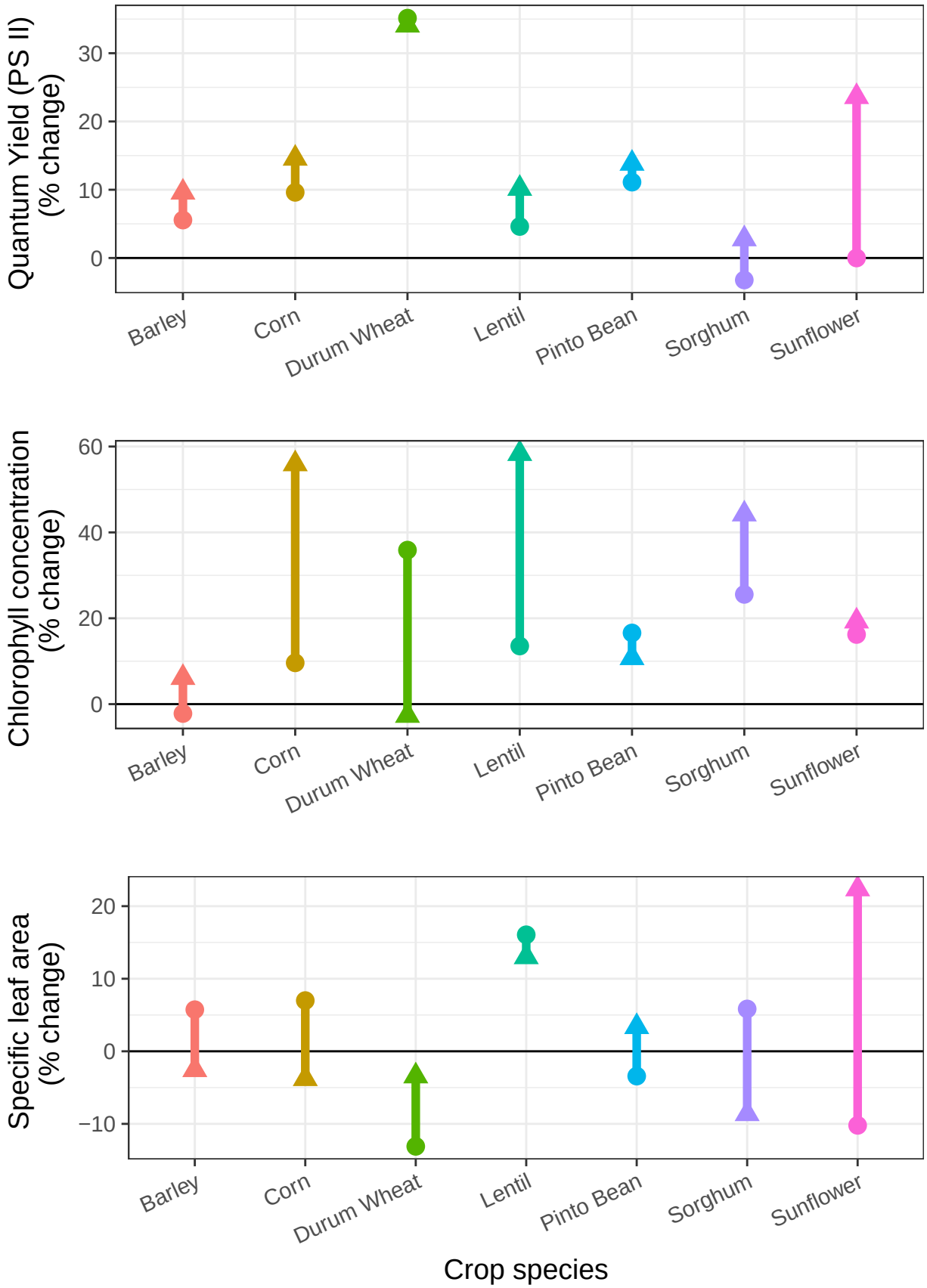

Figure 7: Physiological responses to dust expressed as percent difference between dust-exposed and un-exposed control plants. Symbols denote replicate blocks, which are connected by lines to denote within-block variability. Data from last of six dust events.

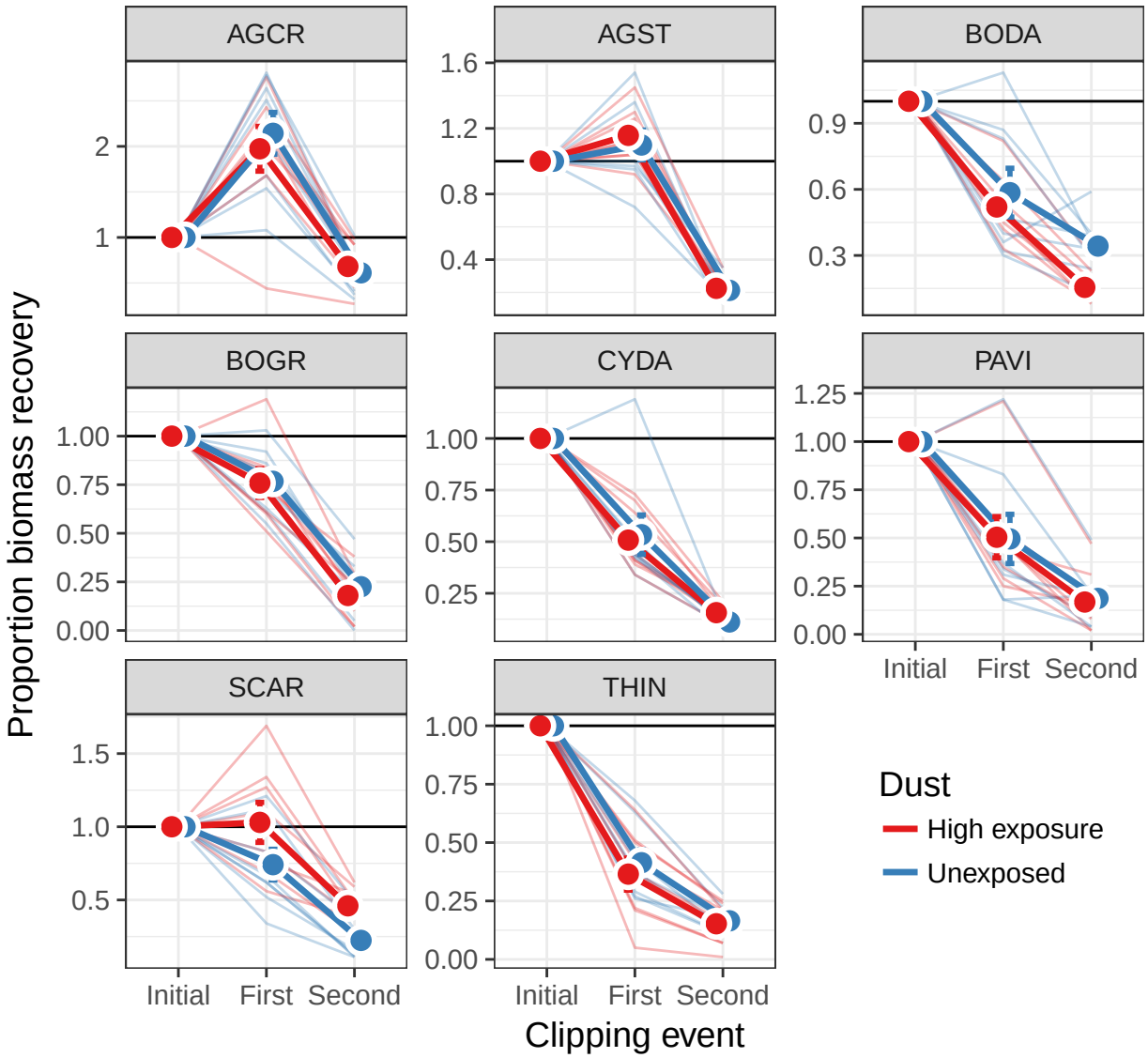

Figure 8: Dust exposure showed no pattern of effect for any species on recovery of perennial grasses following two clipping events. Thin lines in background trace recovery of individual plants (pots); bold lines, points, and error bars show mean (+/- s.e.) of exposure groups.

Sociological component

Research objectives

- Identify primary concerns of rural residents of the Bakken region with respect to energy development impacts on agricultural and natural resources as well as local communities.
- Identify priorities for research needs and extension support in Bakken communities, particularly for the development of research, education, and other support/assistance programs by North Dakota state institutions and agencies.

Results

Focus group outcomes Focus group participants in Watford City, Stanley, and Williston identified a breadth of issues relating to agricultural and natural resources, local communities, and the practice and policy of energy development in rural western North Dakota. These issues related to four primary themes (Table 1): (1) Local communities and local services, (2) Health/safety concerns related to traffic, (3) Issues relating to the operation/management of farms and ranches, and (4) Relationships with energy companies and their representatives.

Table 1: Summary of topics identified by participants in three focus groups in the Bakken oil patch of North Dakota, organized within four thematic areas defined through qualitative data analysis. Specific questions were crafted from each topic and a mail survey conducted with rural residents of the Bakken region to determine the degree to which focus groups represented the broad community in defining issues related to energy development impacts on agricultural, social, and natural resources.

Local communities and local services
Changing demographics: retirees leave, but some young folks return for jobs
Increased population strains local services (ambulance, fire, police, schools)
Too little revenue returned to local communities, and takes too long
Health and safety concerns related to traffic
Dust, spills, leaks, and industrial chemical use pollute environment
Energy activity increases traffic and makes rural travel difficult, dangerous
Increased rail activity makes crossing rights-of-way time-consuming
Farm and ranch management
Road dust reduces crop yield, hay and range productivity
Travel between tracts is slow, dangerous
Compensation inadequate; money not enough to cover time lost
Difficult to monitor distant tracts, some leases being terminated
Soil disturbance, long reclamation time interfere with conservation
Relationships with energy industry
Energy companies and their representatives lack respect for local lifestyle
Energy companies and their representatives are aggressive and too money-centric
Legal jargon is confusing and companies don't begin with fair offers, negotiation

Research priorities identified by survey respondents

Agricultural and Natural Resource concerns Traffic was the most-frequently mentioned concern raised by survey respondents and the only concern raised under both Agriculture and Natural Resources (20 instances) Social Issues (14 instances) (Table 2). Among Agriculture and Natural Resources concerns related to traffic, responses focused on dust and traffic volume. Respondents were concerned about negative impacts of dust on crops, livestock, and pets; one described how dust deters livestock from grazing near roads, which causes overgrazing elsewhere. The other concern about traffic was difficulty moving farm equipment on local roads. Two respondents specifically noted that they terminated leases for land far from their home place, and survey respondents of all impact categories tended to agree with this complaint.

Table 2: Summary of issues respondents of mail survey gave in hand-written responses to two questions prompted by "Please tell us your main concern regarding agriculture and natural resources..." and "...social issues," respectively. Issues are grouped by theme and are followed by the number of specific mentions in text analysis.

A. Agricultural and Natural Resource concerns		
Environmental		
Pollution (22)	Water (13)	Wildlife and ecosystems (11)
Dust (10)	Reclamation/restoration (10)	Spills and leaks (10)
Litter (5)	Fracking (4)	Air (4)
Erosion (2)	Cultural resources (1)	
Farm and ranch management		
Impacts on production (17)	Land area loss (15)	Land value (2)
Energy infrastructure and operations		
Traffic (20)	Pipelines (8)	Flaring (1)
Policy		
Industry relations (21)	Regulations (8)	Government (6)
Property rights (6)		
B. Social Issues concerns		
Community		
Crime (30)	Services (25)	Demographics and dynamics (22)
Cost of living (12)	Way of life (9)	
Policy		
Government (7)	Revenue (6)	Industry relations (4)
Utilities and roads		
Traffic (14)	Infrastructure (6)	Dust (1)

Survey respondents raised several overlapping concerns about environmental impacts of energy production—for example, most concerns about water related to pollution of the groundwater local residents rely upon for drinking, although other water-related concerns included overuse of scant ground and surface water resources as inputs in hydraulic fracturing. Concerns about pollution and spills/leaks obviously overlapped and two major trends emerged among these responses: concerns about long-term effects on farmland due to spilled, highly-saline wastewater from hydraulic fracturing, and concerns about the quality of workmanship over the long-term, with questions about when oil-related infrastructure will crumble and cause even more problems

than experienced during development and initial production phases.

From these data, it appears that bottlenecks in successful soil reclamation and vegetation restoration arise from a lack of willingness or unfamiliarity on the part of energy companies and are exacerbated by a lack of policy and resources to regulate recovery, rather than a lack of science on how such processes should proceed. Focus group participants described how local landowners and lawyers were becoming savvy about how reclamation/restoration practices and standards must be included in easements prior to construction impacts, as well as how energy companies increasingly seek guidance on local best management practices from public resources like USDA-NRCS agents.

Social Issues concerns Crime was the often-most reported social concern (30 instances, Table 2) and echoed statements by focus group participants. Focus groups and survey respondents cited an increase in criminal activity—mostly unspecified, but several mentioned drugs, theft, and prostitution—on account of increased population and a greater degree of transience related to the demographics of the energy industry. While actual risk from increased criminal activity might be overstated, these concerns speak to a widespread sense among both focus group members and survey respondents that the rural way of life these community members value is changing—in fact nine survey respondents specifically mentioned threats to way of life or culture in their handwritten responses and focus group participants expressed feelings of alienation resulting from unsmiling faces in town and unreciprocated waves on rural roads.

Overlapping considerably with crime were concerns over recent changes in the demographics of local communities on account of energy-related activity (22 instances, Table 2). These responses showed the most variability in respondent perceptions of energy-related impacts, ranging from the intolerant—"Everyone that comes here should act like us and speak English"—to the considered—"we always had 1% of our population that were bad and/or disruptive . . . but now we have 1% or less say of 5000 rather than 1% of 1000. Change is hard to accept and will take time." Aside from specific concerns about increased criminal activity, survey respondents expressed general concern that oil workers expected support from social services—often provided informally by local churches and community groups—without "paying in" to these institutions through regular attendance, donation, or volunteering.