AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
FUNDING CYCLE 2019 – 2021

TITLE: How does continual straw removal affect biological, chemical and physical indices of soil health?

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EXECUTIVE SUMMARY:

The aim of this work was to determine if straw management and stand age affects soil health outcomes. In addition we looked at the effect of soil clay content on soil health. To accomplish this, fourteen paired sets of fields were sampled (28 fields), representing tall fescue fields with either a history of full straw chop back ("full straw") or continuous straw removal ("baled") for a comprehensive assessment of 15 soil health indicators that included measures of soil nutrient status, physical status and biologic activity. Of our measured soil health parameters, only soil potassium (K) content was significantly higher in full straw fields ($p=.002$) (Table 1). Soil phosphorous ($p=0.066$) and 96hr respiration rates ($p=0.051$) were elevated in full straw fields. Total soil N and C increased with stand age ($p=0.018$ and $p=0.028$, respectively). Soil clay content had a significant effect on most soil health parameters; the only parameters not affected by clay content were: K, pH, bulk density, and potentially mineralizable nitrogen. Active C, respiration, and calcium were all positively correlated with clay content in full straw fields only, demonstrating a significant interaction between clay and residue that improved these soil health measures. Similarly, P levels declined with increasing clay, but more strongly so in the baled fields. Total C also increased more strongly with stand age in the full straw fields.

Together this data provides a valuable set of baseline data to help growers interpret soil health measures in the future by providing a robust and documented dataset from regional soils and cropping systems. Our data shows that soil clay content was a powerful driver of many soil health outcomes and should be taken into account when analyzing soil health data from Willamette Valley soils. When interactions between soil clay content, stand age and residue are considered, we saw that total carbon, microbial activity and nutrient retention increased in fields with full straw loads.

OBJECTIVES:

1. Evaluate soil health measurements under bale versus full straw chop-back management practices in tall fescue seed crops
2. Explore relationships between soil health measures and key soil/site properties (i.e. texture and stand age) in tall fescue seed crops

3. Educate growers and industry on the soil health assessment process and what factors drive change in the different measurements

PROCEDURES:
A total of 34 fields were sampled in either April 2019 (22 fields) or April 2020 (14 fields), representing 17 paired fields from 17 sampling sites. Fields were identified prior to sampling and selected to meet a set of criteria. All fields were planted to tall fescue and were greater than four years in age (one three year old field was included to get better representation in the North Valley) (Figure 1). Fields with a history of full straw chop-back ('full straw') were paired with similar aged stands on the same or related soil series in a nearby field (<10 miles away), that had a history of continuous straw removal ('baled'). To be considered full straw management, the field had to have been managed under the full straw practice for 75% of stand years. The fields sampled almost always had more than one soil series. We used NRCS soil maps to sample from portions of the field corresponding to dominant soil types and to the best of our ability, to soil types matching the paired field. The most commonly sampled soil series was Woodburn, followed by Dayton and Amity. Additional sites included soil series such as Quantama, Cornelius-Kinton, Huberly, Aloha, Chehalis, McBee, Malabon, Concord, Bashaw, Helvetia and Laurelwood.

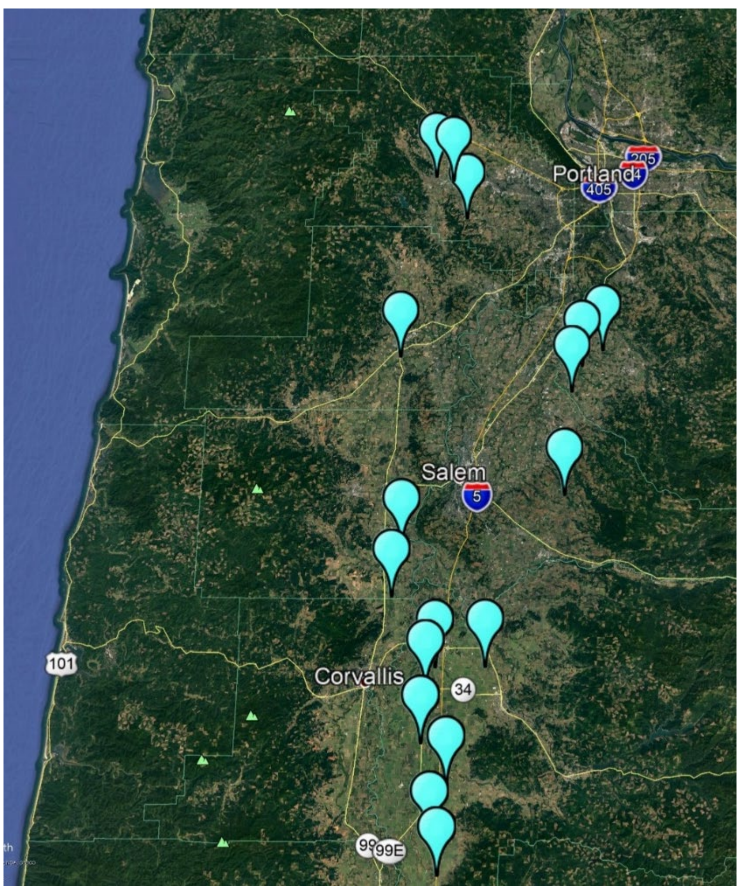

Figure 1. Map of the Willamette Valley showing the general location of the 14 sites (one full straw and one baled field at each).

All fields were soil sampled between April 2019 or April 2020. Sampling occurred over two years simply to break up the field work and allow us to sample enough fields at the same time of year. In most cases, paired fields were sampled on the same day. Three zig-zag transects per field were sampled and analyzed separately. Transects were placed semi-randomly in uniform parts of the field and in portions of the field aligned with soil types in the matching paired field. Ten soil cores per transect were taken to an 8 inch depth and mixed to form a composite sample. Penetration resistance and bulk density measurements were conducted in the field. Samples for laboratory analysis were stored at 4°C until laboratory analysis was conducted at OSU's Central Analytical Lab. Penetrometer measurements were not conducted in 2020 due to labor constraints (COVID) and given that they did not yield any interesting data from the 2019 dataset.

In addition to the soil health properties listed in Table 1, soil samples were analyzed for texture (% sand/silt/clay). The set of analysis outlined in Table 1, follows the framework and protocols outlined by Cornell University in the Comprehensive Assessment of Soil Health (CASH, https://soilhealth.cals.cornell.edu/). Soil OM was calculated from total C analysis, we report only total C in this report. All analysis was conducted at OSU's Soil Health Lab (formerly the Central Analytical Laboratory). The full protocol and methodology for each analysis can be obtained from the OSU Soil Health Lab (https://cropandsoil.oregonstate.edu/shl/soil-health-osu).
To evaluate the fit of pairing between fields, we compared the mean percent clay between the two fields. Sites with greater than 5% difference in clay content were considered unacceptable pairs and were excluded from analysis. Across both years, three sites did not meet this criteria and were not used. Our final data consisted of 14 sites, 28 fields, each consisting of three replicate samples for a total of 84 samples.

Table 1. Soil health parameters measured in this study

Chemical/nutrient	Physical	Biologic
pH	Bulk density	Soil respiration (24 and 96hr)
Electrical conductivity (EC)	Wet aggregate stability (WSA)	Total C%, total N%
Mehlich-3 extractable P,K,Ca,Mg		Active C (permanganate oxidizable C)
Cation exchange capacity (CEC)		Potentially mineralizable carbon (PMN)

All statistical analysis was done in R (R Core Team). To determine the effect of residue management and stand age on soil health outcomes, we utilized a linear mixed effects model with soil health variable as the dependent variable, residue management and stand age as independent variables, soil clay content as a covariate, and field was nested within site as a random effect. Stand age was included as an independent variable in our ANOVA, as it was something we controlled for in our field selection and soil clay content was included as a co-variate, as it was determined from lab analysis after sampling. Correlation coefficients and p-values were derived from Pearson correlations between clay content, stand age and soil health variables. Correlations were run on the entire dataset and as well as full straw and baled datasets independently.

SIGNIFICANT ACCOMPLISHMENTS:

- All intended field work and data analysis has been completed
- This work has been presented at our fall Extension grower meeting (more than 300 in attendance, 2019), as well as academic conferences (AGU 2019 and SSSA Annual Meeting 2020).
- The field selection criteria and some of the fields have been adopted into a soil C project led by Gonzalez-Mateu, Moore and Trippe
- The work has generated important baseline data on the range of values we can expect for these soil health measures from Willamette Valley grass seed systems and will be incorporated into the OSU Soil Health Database.

Effects of straw management

Results of key soil health measures are shown in Figure 2. Among the soil physical properties, bulk density, wet aggregate stability, and cation exchange capacity we observed no differences between the management practices. Among soil chemical properties we found higher K under full straw management (p=0.002), which is not surprising given that the straw contains high amounts of K. When regularly baling, growers typically apply significantly higher rates of potash fertilizer, these results indicate that in general K removal from baling is not adequately being replaced by potash fertilizer applications. Among the biologic soil properties measured, we observed elevated respiration (96 hr test) (p=0.051) and elevated P in the full straw fields (p=0.066). The 24 hr respiration rate, which is the measure most similar to the commercially available Solvita 'Burst' test, tended to be higher in the full straw fields but differences were not significant. Respiration rates reflect microbial activity but also availability of a food source for microbes, in this case likely C from the straw.

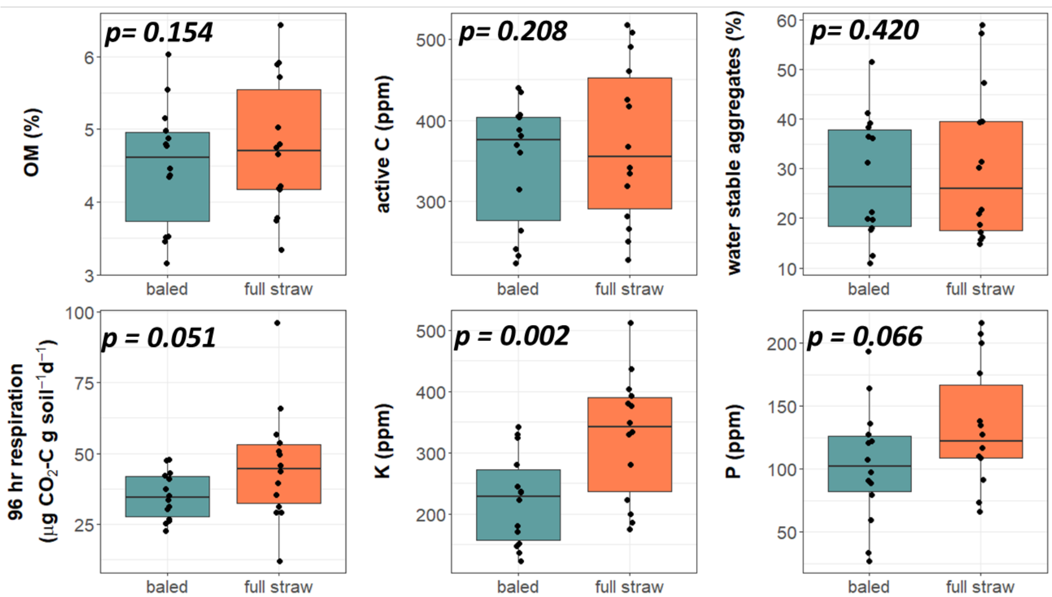

Figure 2. Box plots of key soil health properties in the baled and full straw fields (n = 14). Each point represents a field and is the average of the three transects. The top of each box represents the 25th percentile, while the lower end of the box represents the 75th percentile (i.e. 25% of observations were above and below the boxed area). Solid bold lines indicate the mean for each management, respectively.

In our overall ANOVA, total C and active C were not affected by straw management (Table 2). The lack of straw management effect on total C could be attributed to the large size of the soil C pool and/or to more dominant factors which affect total C and OM, such as tillage and below ground inputs. The soil total C pool is large and it often takes a long time and significant management changes to detect changes in this pool. We hypothesized that depth stratification may also play a role, as straw C in these systems may be more concentrated in the surface layers. However, in 2020, subsamples from the 0 to 3" depth were analyzed for total C, OM and active C only but still no effect of straw management was observed (Table 3). Active C is a smaller pool of C that is thought to be more digestible and used relatively quickly by the microbial community; it has been observed to be more responsive to management practices (Awale et al., 2017). However, we found no differences in active C between the management practices.

Effect of stand age and clay content on soil health measures
Both stand age and soil clay content were expected to influence soil health measures. The older a stand, the more time had passed since it was disturbed by tillage; and all else being equal, soil C increased with clay content because of the high and negatively charged surface area on clays which retain OM. Thus stand age was included as an independent variable in our ANOVA, as it was something we controlled for in our field selection and soil clay content was included as a co-variate. We also explored the relationships of stand age and soil clay content on soil health measures through linear regression. Stand age ranged from three to 18 years, with an average of 7.6 years. Clay content ranged from 15.4 to 47.8%, with an average of 25.7%.

Soil clay content had a significant effect on most soil health parameters; the only parameters not affected by clay content were: K, pH, bulk density, and potentially mineralizable nitrogen (Figure 3, Table 4). Active C, respiration, and calcium were all positively correlated with clay content in full straw fields only, demonstrating a significant interaction between clay and residue that improved these soil health measures. Similarly, P levels declined with increasing clay, but more strongly so in the baled fields. Total N and C were significantly affected by stand age (Table 3) and in particular, total C and N increased more strongly with age in the full straw fields (Figure 4, Table 5).

BENEFITS & IMPACT:
Together this data provides a valuable set of baseline data to help growers interpret soil health measures in the future by providing a robust and documented dataset from regional soils and cropping systems. Our data shows that soil clay content was a powerful driver of many soil health outcomes and should be taken into account when analyzing soil health data from Willamette Valley soils. When interactions between soil clay content, stand age and residue are considered, we saw that total carbon, microbial activity and nutrient retention increased in fields with full straw loads. In sum:

- This project demonstrated mostly positive changes in soil health in response to retaining grass seed residues in the field.

- Many of the soil health indicators were correlated with each other, this study can then serve as a step forward to identifying a minimum dataset for soil health assessment.

- This work will inform future field research. It identified the range in soil health properties present in contemporary soils used for grass seed production.

- This dataset can serve as preliminary data in proposals for soil health research. Proposals with preliminary data have a higher success rate.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM:
FUTURE FUNDING POSSIBILITIES:

Table 2. P-value results of a linear mixed model with residue management and stand age as independent variables. Soil clay content was considered a covariate.

	chemical/nutrient							physical		biologic					
	K[a]	P[a]	Ca[a]	Mg[a]	pH	EC	CEC	bulk density	WSA	total N	total C	PMN[C]	Active C	24 respiration	96 hr respiration
residue	0.002	0.066	0.318	0.685	0.677	0.939	0.437	0.317	0.420	0.383	0.154	0.306	0.208	0.150	0.051
stand age	0.536	0.803	0.807	0.854	0.489	0.695	0.880	0.108	0.556	0.018	0.026	0.364	0.240	0.922	0.452
clay	0.675	0.005	0.001	<.001	0.805	0.001	<.001	0.314	0.048	<.001	<.001	0.465	0.026	<.001	<.001
residue*stand age	0.093	0.094	0.708	0.162	0.811	0.787	0.658	0.491	0.009	0.049	0.119	0.383	0.432	0.382	0.469

[a]Mehlich-3 extractable nutrients, [b]WSA = water stable aggregates, [C]PMN=potentially mineralizable nitrogen

Table 3. 2020 surface soils (0-3”) P-value results of a linear mixed model with residue management and stand age as independent variables. Soil clay content was considered a covariate.

	active C	total N	total C
residue	0.262	0.237	0.137
stand age	0.253	0.012	0.020
clay	0.050	0.006	0.005
residue*stand age	0.381	0.271	0.255

Table 4. Correlations between soil clay content and measures of soil health. Pearson correlations were conducted on field means. Correlations are presented for the entire dataset, baled fields only, and full straw fields only. P-values <0.05 are indicated in bold italics.

	overall		baled		full straw	
	Pearson r value	p-value	Pearson r value	p-value	Pearson r value	p-value
K[a]	-0.045	0.819	-0.010	0.972	-0.039	0.895
P[a]	-0.500	***0.007***	-0.656	***0.011***	-0.362	0.204
Ca[a]	0.605	***0.001***	0.389	0.169	0.804	***0.001***
Mg[a]	0.867	***<0.001***	0.861	***<0.001***	0.886	***<0.001***
pH	-0.156	0.428	-0.508	0.064	0.168	0.566
EC	0.692	***<0.001***	0.738	***0.003***	0.671	***0.009***
CEC	0.690	***<0.001***	0.545	***0.044***	0.837	***<0.001***
WSA[b]	0.577	***0.001***	0.639	***0.014***	0.550	***0.042***
Total N	0.583	***0.001***	0.642	***0.013***	0.541	***0.046***
Total C	0.651	***<0.001***	0.769	***0.001***	0.571	***0.033***
Active C	0.459	***0.014***	0.417	0.138	0.532	***0.050***
PMN[c]	0.181	0.356	0.233	0.422	0.146	0.618
24hr Resp.	0.546	***0.003***	0.360	0.207	0.773	***0.001***
96hr Resp.	0.540	***0.003***	0.370	0.192	0.789	***0.001***

[a]Mehlich-3 extractable nutrients, [b]WSA = water stable aggregates, [c]PMN=potentially mineralizable nitrogen

Table 5. Correlations between stand age and measures of soil health. Pearson correlations were conducted on field means. Correlations are presented for the entire dataset, baled fields only, and full straw fields only. P-values <0.05 are indicated in bold italics.

	overall		baled		full straw	
	Pearson r value	p-value	Pearson r value	p-value	Pearson r value	p-value
K[a]	0.109	0.581	-0.235	0.418	0.427	0.128
P[a]	0.037	0.852	-0.233	0.422	0.325	0.256
Ca[a]	-0.066	0.738	-0.057	0.845	-0.079	0.787
Mg[a]	-0.004	0.982	0.091	0.757	-0.094	0.749
pH	-0.156	0.429	-0.134	0.648	-0.180	0.538
EC	-0.115	0.560	-0.119	0.685	-0.114	0.699
CEC	-0.054	0.787	-0.042	0.886	-0.067	0.821
WSA[b]	0.176	0.371	-0.153	0.601	0.465	0.094
Total N	0.388	***0.041***	0.221	0.447	0.559	***0.038***
Total C	0.360	0.060	0.187	0.523	0.540	***0.047***
Active C	0.106	0.591	0.188	0.520	0.045	0.879
PMN[c]	0.163	0.407	0.285	0.324	0.052	0.859
24hr Resp.	0.014	0.945	0.259	0.371	-0.083	0.777
96hr Resp.	0.117	0.555	0.404	0.152	0.022	0.941

[a]Mehlich-3 extractable nutrients, [b]WSA = water stable aggregates, [C]PMN=potentially mineralizable nitrogen

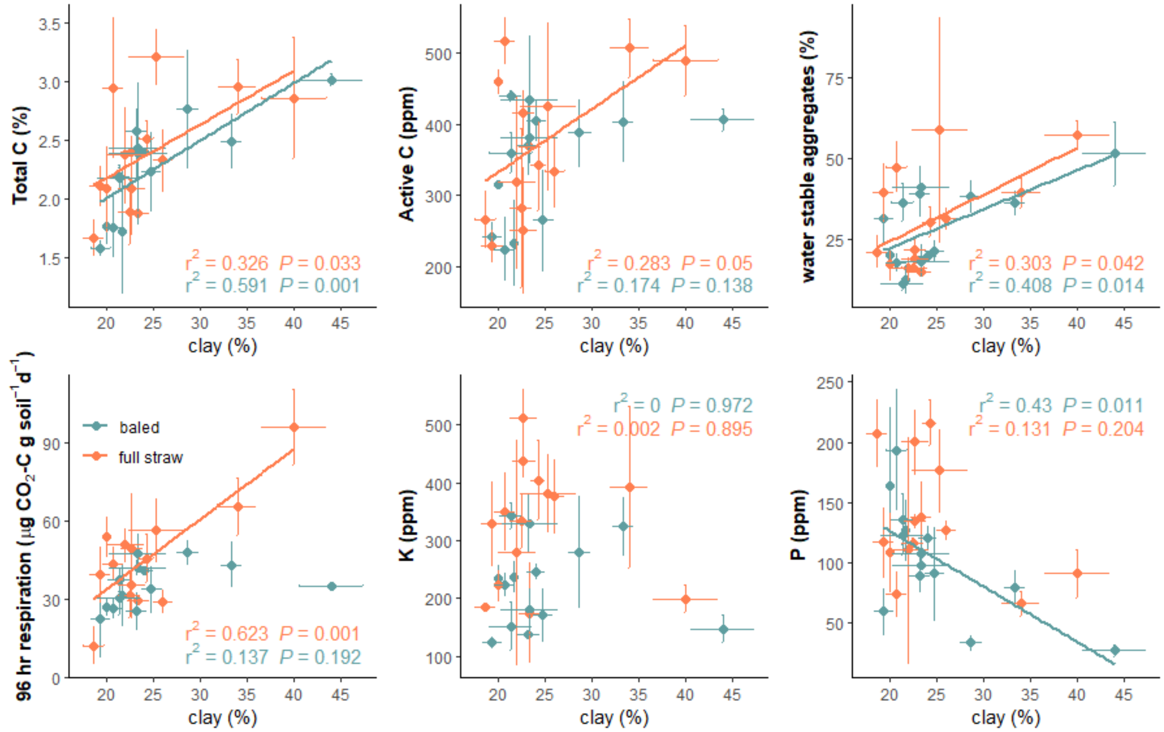

Figure 3. Relationships between soil clay content and select soil health properties for full straw (salmon) and baled (blue). Each point represents a field and is the average of the three transects. A regression line is shown only when the regression was significant at $p<0.05$.

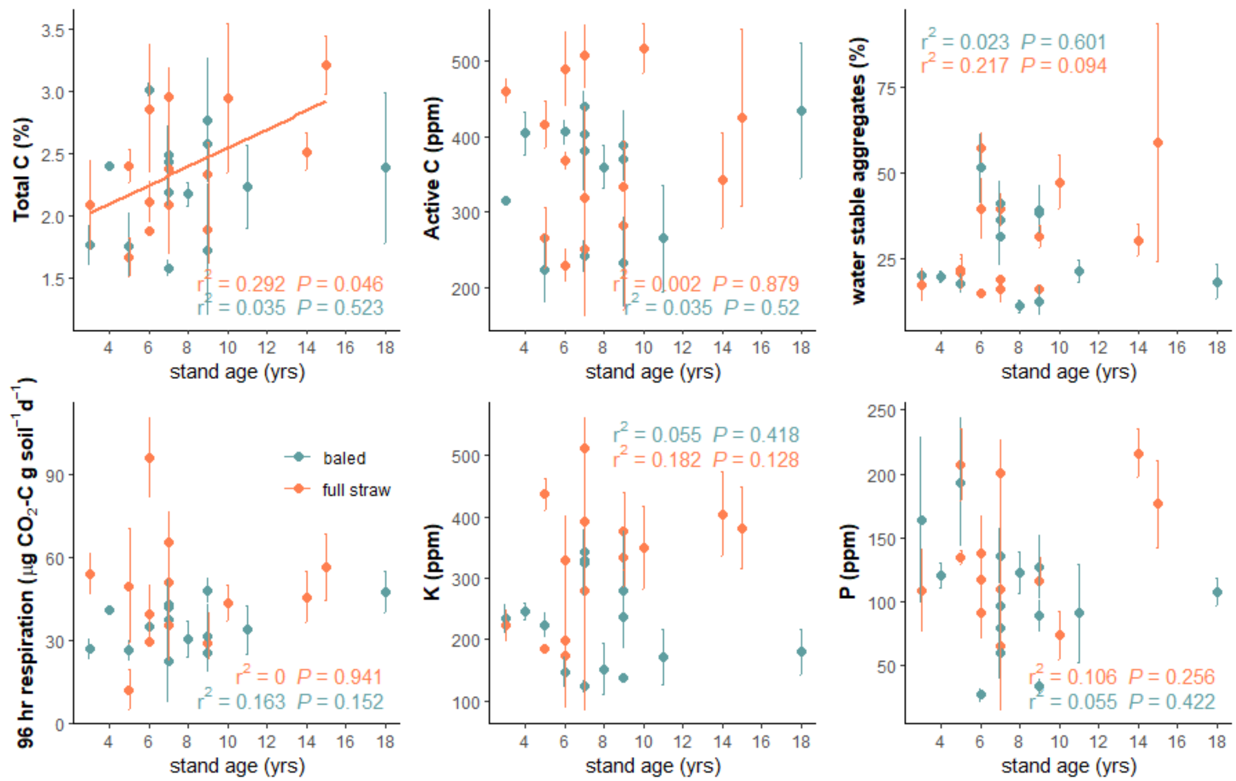

Figure 4. Relationships between stand age and select soil health properties for full straw (salmon) and baled (blue). Each point represents a field and is the average of the three transects. A regression line is shown only when the regression was significant at $p<0.05$.