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Integrating Hog Grazing in a Cover-vegetable Rotation for Healthy Soil

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Abstract

Ongoing agricultural research is investigating the potential of integrated crop and livestock production systems to maximize land-use, improve ecosystem functioning and reduce of waste. This study integrates hogs and cover crops with vegetable production to determine the viability, applicability, and scalability of the system. Research took place over three years in Delta, British Columbia, Canada. Significant differences in soil physical and chemical characteristics were present in the top layer of the soil profile between grazed and tilled systems, but did not carry down to deeper depths. Corn yields were greater in grazed treatments relative to tilled ones, potentially highlighting nutrient differences from the hog grazing systems.

Institute for Sustainable Food Systems

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1.0 INTRODUCTION

In recent generations, modern agriculture has become increasingly specialized, often resulting in the loss of integrated crop and livestock systems. At the same time, negative effects of intensive agriculture on biodiversity, ecosystems (MEA, 2005), climate change and water quality have become increasingly apparent (Stoate et al., 2001). Specialization of farming systems can lead to environmental harm via overconsumption of natural resources, nitrate pollution, degradation of soils from over-reliance on mechanical tillage and greenhouse gas emissions (Peyraud et al., 2014).

Since the 1990s, many studies have elucidated the benefits of crop-livestock systems through maximization of land-use, ecosystem functioning and reduction of waste (Hendrickson et al., 2008; Russelle et al., 2007). Other examples include the use of crop-pasture rotations to maintain soil organic matter and soil fertility (Dalal et al., 2004; Franzluebbers and Stuedemann, 2008), reduce erosion risk (Robertson et al., 2009), improve weed seed control and improve forage provision (Popay and Field, 2017). Ryschawy et al. (2012) state that nutrient cycling and soil fertility can be improved at field and farm scale levels by animal-waste recycling and by including forage rotations into field-crop systems.

Integrated Crop-livestock Systems (ICLS) consist of multiple enterprises and functions which interact in space and time providing benefits from their synergistic resource transfers (Hendrickson et al., 2008). ICLS' may represent a model of sustainable farming that when following agroecological principles of nutrient recycling, land and animal stewardship, and efficient use of land and resources have the potential to be widely adopted by small-scale farmers (Sekaran et al., 2021). In the past decade, many small to large sized farms in North America and the world have re-integrated rotational livestock grazing into their farm management systems to mitigate on-farm environmental impacts and diversify or expand their revenue streams (Teague and Kreuter, 2020). This trend is consistent with increasing market demand for ethically-sourced livestock products and the need for crop production practices that mitigate climate change.

Amid this trend, the impacts of integrated crop-livestock on soil and nutrient cycling have not been comprehensively studied and understood (Franzluebbers and Stuedemann, 2008). The research conducted thus far has almost exclusively focused on cattle systems and no studies have been found that investigate the impacts of strip-grazing hogs on soils and its viability for integration into annual cropping systems to improve yields and crop nutritional quality (Ryschawy et al., 2012). Significant research has investigated animal stocking rates on pasture or comparing grazed areas to untouched rangeland (Bauer et al., 1987; Lavado et al., 1996; Rachuonyo and McGlone 2007; Tobin et al., 2020). However, little research has been directed at the impact of grazing animals as a substitute for tillage in agricultural models. Despite heightened interest and the benefits of livestock integration, the complexity of such systems constrain adoption. This increased complexity in management coupled with the dearth of information renders hog integration into cropping systems daunting even for interested farmers.

Research was conducted involving the integration of hogs and cover crops with vegetable production to determine the viability, applicability, and scalability of the system. Research sought to determine whether a hog/crop-rotation system can help vegetable producers reduce tillage, soil compaction, and weed pressure, while improving soil structure, drainage, aeration, organic matter content, and microbial biomass, as well as increasing subsequent crop yields. Research investigated the impacts of integrating hog strip grazing in a market vegetable –cover crop rotation system on soil quality, the nutrient life cycle from soil to plants, and subsequent crop yields

2.0 MATERIALS AND METHODS

Research was conducted from 2019 to 2021 at Tsawwassen, BC, (49°02’N, 123°04’W) on Spetifore and Ladner silty clay loam soils (fine, fluvial, poorly drained), 0.3m above sea level with zero percent slope, and annual precipitation of 917mm in 2018. Research was conducted for three field seasons from 2019 to 2021. In 2019, one field was set up for hog grazing and cover crops. In the 2020 field season two separate research fields were established; one field in vegetables which had been under grazing treatments in 2019, and a second one to go into grazing treatments during the 2020 field season. Finally, in 2021, one research field was cultivated in vegetables, the field that had been in grazing in 2020. This staggering of field usage led to two years of research for both hog grazing and vegetables following hog grazing.

2.1 Hog Grazing

Research was set up using a randomized complete block design with grazing as main plot and replicated four times. A one-half hectare field was established with eight 0.07-hectare plots 4 for grazing and 4 for tractor tillage. Each main plot was divided into 6 subplots of 9.1 x 11.6 m (Figure 1). Once staked, soil cores of 0-15 cm and 15-30 cm from each subplot were taken to measure available N and active carbon. Additionally, electrical conductivity (EC) and volumetric water content (VWC) (4 in. rod, TDR 150 Soil Moisture Meter, Spectrum Technologies, Aurora, IL). Following initial soil data collection, field preparation began which included chisel plow (Brillion chisel plow, 92 in.), and then harrowed (Lehman rolling cultivator, 370) a week later. All implements used throughout the research were used with a 57-horsepower tractor (Kubota, LA1065). Next. one pass of the disc followed by broadcasting of a spring cover crop (See table 1 for cover crop mixtures) (Spin Spreader, Braeber Equipment, Abbotsford, BC), followed by a second pass of the disc to incorporate the cover crop seed. Following 65 days of cover crop growth, pasture fencing for the grazing treatments was erected and hogs moved into the first subplot (Figure 2).

For the grazing treatments, two hogs were put into the first subplot of each of the 4 grazing treatment main plots All eight hogs were Berkshire and Duroc cross. The hogs were six months old (approx. 45 kg) when they entered the grazing plots. Hogs were moved through the six grazing units (subplots) sequentially in the manner of strip-grazing. Hogs were moved from one subplot to the next when most of the cover crop had

Figure 1. Map of research field showing main treatment plots of grazing (yellow) and tillage (white) as well as direction of hog movement through subplots. Red boxes show example of one random main plot and one random subplot.

Block 1		Block 2		Block 3		Block 4	
6	12	18	24	30	36	42	48
5	11	17	23	29	35	41	47
4	10	16	22	28	34	40	46
3	9	15	21	27	33	39	45
2	8	14	20	26	32	38	44
1	7	13	19	25	31	37	43
A	B	C	D	E	F	G	H

been uprooted and laid on the ground, with no fewer than 30% of soil exposed and before the hogs could begin cratering. This usually corresponded with 5-10 days depending on cover crop growth stage, weather and soil moisture. The day before hogs were moved into the subsequent subplot, a summer cover crop (see Table 1) was broadcast by hand for the hogs to incorporate via trampling. After 24 hours, the hogs were moved onto the next subplot. Table 2 illustrates hog movements and cover crop spreading dates within grazing treatments throughout the season. Once the hogs grazed all 6 subplots, they were returned to the first subplot to re-initiate the process for the second time. This time, a winter cover crop (see Table 1) was broadcast into subplots 24 hours before each hog move. Hogs were removed from the grazing plots when the last subplot had been grazed a second time (mid to late September).

In the tillage treatments, the spring cover crop was mowed (Woods RC5, Oregon, IL) and harrowed (Lehman rolling cultivator, 370) when the hogs were halfway through the subplots in the grazing treatments. Summer cover crop (Table 1), was then hand broadcasted, a second disc pass incorporated the seed. The same steps were completed to for the final cover crop seeding of the season (Table 1) when hogs were halfway the summer cover crop forage. Tillage terminated the summer cover crop, winter fall cover crop was hand broadcast, and followed by a pass of the disc to incorporate seed.

Figure 2. Pairs of hogs in the first subplot with spring cover crop in 2020.

Table 1. Cover crop species and seeding rate for grazing and tillage treatment.

Cover crop species†	Seeding rate	% of mix	Kg per plot	Kg per subplot	45% more in grazing
Spring Mix	kg/hectare		.07 ha	.012 ha	kg/subplot
Oats	81	43	5.7	0.97	n/a
Ladino clover	5.4	3	0.38	0.06	n/a
Field peas	103.5	54	7.2	1.2	n/a
Summer Mix					
Sudex-sudan		36	2.4	0.41	0.59
Buckwheat	54	58	3.8	0.65	0.96
Ladino clover	5.4	6	0.38	0.06	0.09
Winter Mix					
Fall rye	47.3	75	3.3	0.56	0.82
Hairy vetch	15.8	25	1.1	0.19	0.27

†Species scientific names in the order that they appear in the table: Avena sativa, Trifolium repens, Pisum sativum, S. bicolor var. Sudanese, Fagopyrum esculentum, Secale cereale, Vicia villosa

Table 2. Cover crop seedings and hog movements in 2019 and 2020.

2019		2020	
Spread Cover Crop	Moved Hogs	Spread Cover Crop	Moved Hogs
July 22	July 23	July 14	July 15
July 29	July 30	July 22	July 23
August 6	August 7	July 28	July 29
August 12	August 13	August 3	August 4
August 19	August 20	August 11	August 12
August 25	August 26	August 17	August 18
August 28	August 29	August 25	August 26
September 4	September 5	September 1	September 2
September 9	September 10	September 6	September 7
September 15	September 16	September 10	September 11
September 18	September 19	September 17	September 18
September 25	September 26	September 23	September 24

2.2 Vegetable production

In 2020 and 2021, the field that had been grazed the year prior was put into vegetables. Before prepping the field for vegetables, soil parameters were collected from all subplots

These included VWC, EC, and penetration resistance (4 in. rod, TDR 150 Soil Moisture Meter, Spectrum Technologies, Aurora, IL, and Dickey-John Soil Compaction Tester, Grainger, Thornhill, ON). Soil cores of 0-15 cm and 15-30 cm were taken for available N and active carbon and cylinders of 331 cm3 to calculate Bulk density. Following soil data collection, any remaining biomass was mowed (Woods RC5, Oregon, IL) and harrowed (Lehman rolling cultivator, 370). After several weeks to allow for biomass breakdown, the field was harrowed again, compost was spread at a rate of 2.5 cubic yards per main plot (targeting 10 cu yd/acre) and then incorporated (Maschio Gaspardo, 180C).

Each main plot was planted with 2 rows of butternut squash (Victory F1, West Coast Seeds, Delta, BC) and 6 rows of corn (2021, Kandy King, West Coast Seeds, Delta, BC and 2020 Hero XR Untreated Sweet Bicolor, Osbourne, Mt Vernon, WA) (Figure 3). Squash was direct seeded by hand at 1 m spacing in row and 1.5 m between rows and corn was seeded using a Jang seeder (JP-1, Jang Automation, Chungcheongbuk-do, Korea) at 1 m between row spacing and 11.4 cm in row. Weed assessment data from each subplot in the squash and corn using a 0.3 x 0.3 m quadrat was taken on June 11 and July 6, 2020 and June 30, 2021. After each weed assessment plots were hand weeded to weed free. Corn harvest for research was on September 25, 2020 and October 6, 2021, using 1-meter cross-sections across all rows in each plot. Stand count per quadrat, number of ears, and total weight were recorded. Entire squash plots were harvested on September 30, 2020 and September 29, 2021 and weighed separatly as marketable and unmarketable.

Figure 3. Two rose of butternut squash and six rows of sweet corn planted in each main plot in 2021, following the grazing treatments completed in 2020.

3.0 RESULTS

3.1 Environmental conditions

In 2020, there were 263 mm of rain throughout the growing season (April – September), but during the growing season of 2021, this fell to a total of 247 mm. While although both years were above the total rainfall for the growing season of the previous 10-year average (231 mm), in 2021 after June 16 there was no precipitation until August 6 (51 days). Additionally, although total rainfall in August was 37 mm, almost half (16mm) occurred on one day (August 6). The average temperature from April through September was 16.3°C and 15.9°C for 2020 and 2021, respectively, higher than the past 10-year average. In 2021, average high temps for the growing season were also higher than the 10-year average, 20.1°C compared to 19.5°C. Specifically, June of 2021 was abnormally hot, with an average temp of 18.3°C and high temperatures hitting 34.5°C. Due to below average rainfall and high average temperatures, the results of this research during the 2021 growing season were representative of severe drought conditions. Drought conditions in 2021, particularly during grain fill diminished yield of most summer annuals.

3.2 Soil impacts

Soil parameters were collected before grazing and tillage treatments were conducted as well as after (this will be referred to as timing for the duration of the article). Impact of treatment and timing depended on the soil parameter measured. The main effect of timing was significant for bulk density, with bulk density after treatments completed at 0.98 g/cm3, as compared to before 1.09 g/cm3. These results may indicate stocking hog rates were low enough to reduce compaction from hooves and increased bulk density. This is supported by research by Quintern and Sundrum (2006).

At the shallower depth of 0-15 cm, there was a treatment by timing interaction for both available Nitrate (NO3) and available Ammonium (NH4) (Table 3). However, at the deeper depth of 15-30 cm, only timing significantly impacted NO3 and there were no statistical differences for timing or treatment for NH4. Similarly, treatment significantly impacted penetration resistance of the soil at 0-15cm but did not do so at 15-30 or 30-45 cm (Table 3). These results could mean that impacts of this research were present in the top layer of the soil profile, but may not have carried down deeper into the soil profile. This is congruent with our hypothesis as changing soil profiles more than the top few centimeters can take many years (Brantley, 2008). Models have shown that residence times for soil organic matter are commonly estimated at 100 to 1000 years, although some of this material, such as nitrogen, can turn over in under 10 years. (Brantley, 2008). As this research was only carried out over 3 years, it is unlikely we would be able to detect real soil characteristic change throughout the profile.

Timing significantly impacted the soil volumetric water content (VWC) and there was an interaction between timings and treatment for soil electric conductivity (EC) (Table 3). It is probable that timing impacted VWC because the measurement takes a snap shot in time of the soil water content. Since measurements were taken months apart, it is unlikely that timing would not significantly change the soil VWC. However, the treatment interaction for EC potentially means that the treatments were impacting the soils EC as well as porosity and water holding capacity.

Results on the impact of soil properties in this research are congruent with findings on the impacts of grazing to soil. Many studies evaluating grazing land to open rangeland, found minimal negative impacts to soil properties (Bauer et al., 1987; Lavado et al., 1996; Tobin et al., 2020). While these studies only compared grazing to open rangeland, research that evaluated animal stocking rates found negative soil impacts, only where animal stocking rates exceeding 1 AU/ha (Pulido et al., 2018). Thus, with the appropriate number of animals to graze and area, integrating grazing in place of tillage in arable crop land, could very well reduce negative impacts on soil properties.

3.3 Crop yields

There were significantly more total weeds in the 2020 crop season (1,650 per acre compared to 1,000 per acre in 2021), but no statistical differences in weed presence among treatments (Table 4). There were no differences in weed cover or number by type of weeds across treatment or year. In a meta-analysis of the impact of grazing on seed bank and above ground vegetation, Chaideftou et al. (2008) found grazing could increase, decrease or have no effect on the similarity of seed banks and above-ground vegetation. More long-term research is needed to determine the impact of hog grazing on depleting the weed seed bank and rooting perennial weed species.

In 2020, corn yields were larger in the grazed treatments (57,040 kg/acre) than conventional tillage treatments (30,160 kg/acre) (Table 4). Corn yield in 2021 was less than 2020 across all treatments, with 26,280 kg/acre for grazed plots and 25, 840 kg/acre in conventionally tilled (Figure 4). Squash yields inverted the relationship with tillage treatments appearing to have larger yields that grazing treatments. However, there were no statistical differences across treatment or year for squash yields, with an average yield of 4,336 kg/acre. The amount of unmarketable squash was larger in 2021 than 2020 (377 and 1,554 kg/acre, respectively across treatment) but not significantly so. While although squash yields were not statistically different across treatment, the land use of the grazed treatments would have supplied higher economic benefits due to its due of livestock forage. When modeling integrated systems in Brazil, Peterson et al. (2020) found that although soybean yields were typically lower in the integrated systems, the additional forage and livestock production increased total system outputs.

Yields were considerably lower in 2021 due to periods of extreme heat and drought throughout the season. Difference in grazed treatments compared to tillage treatments in 2020 may have been due to nutrient differences rather than resource competition. Short duration grazing management techniques, may hold promise for better manure distribution, particularly as, unlike permanent or semi-permanent pastures, short-term, cover crop pastures then rotate to cash crops (Gardner et al., 1991). Pasturing hogs could help in general distribution and recycling of nutrients (Rachuonyo and McGlone, 2007). Quintern and Sundrum (2006) state that one way to reduce potential nutrient losses in outdoor pig production is optimizing the crop rotation to ensure that nutrients in the soil are used efficiently. Corn could be one optimal crop to follow hog grazing as it is a heavy N user.

3. 4 Conclusions

Grazing and tillage treatment statistically impacted the amount of available NO3 and NH4 at a 0-15 cm depth via an interaction term with timing, and penetration resistance as a main effect. However, treatment had no statistical impact on all three soil parameters at depths deeper. Results of this research were present in the top layer of the soil profile, but did not carry down to deeper depths, potentially highlighting the slow rate of change to soil below the top few centimeters. Vegetable crops following hog treatments were much lower in 2021 than 2020, most likely due to periods of extreme heat and drought throughout the season. Corn yields were greater in grazed treatments than tilled ones, which may have been due to nutrient differences rather than resource competition. Short duration grazing management techniques, may hold promise for better manure distribution as cover crop pastures then rotate to cash crops as well as reduce potential nutrient losses in outdoor pig production by optimizing the crop rotation to ensure that nutrients in the soil are used efficiently. Corn could be one optimal crop to follow hog grazing as it is a heavy N user. Continued research needs to be directed at the impact of grazing animals as a substitute for tillage in agricultural models. Long-term research needs to be sustained to identify the potential benefits of grazing on soil quality in comparison to conventional tillage in livestock integrated systems.

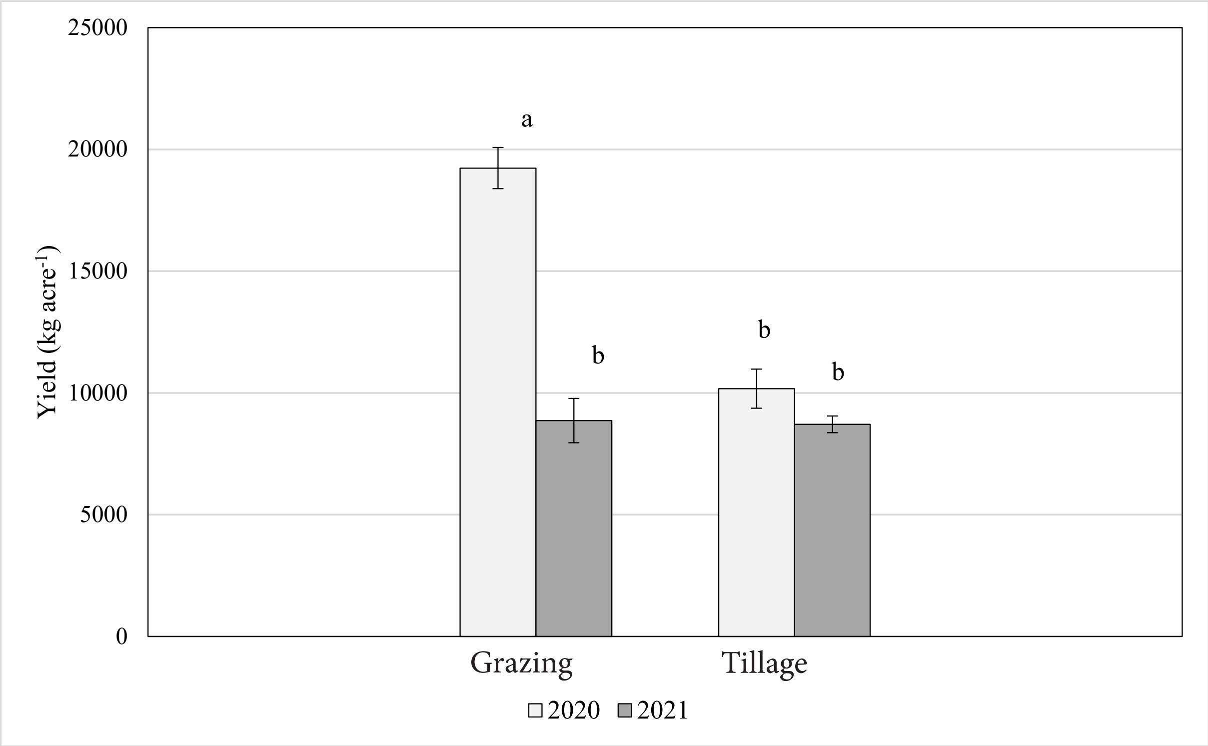
Table 3. The effect of timing on soil available nitrate (NO3) at 0-15cm and 15-30 cm, bulk density (BD), volumetric water content (VWC), and electrical conductivity (EC).

	NO3			BD	VWC	EC	
	0-15 cm		15-30 cm				
Timing	Grazed	Tillage				Grazed	Tillage
	mg kg-1			kg cm^3	%	mS cm^{-1}	
Before	1.64	1.40	1.24	1.09	45.98	0.69	0.84
After	0.85	1.06	0.98	0.98	30.97	0.22	0.17

Table 4. The effect of year (2020 and 2021) on total weeds, broadleaf weeds and corn ears by treatment. volumetric water content (VWC), and electrical conductivity (EC).

Year	Total weeds	Broadleaf	Corn ears	
			Grazed	Tillage
	no. acre^{-1}			
2020	2,144,894	2,089,138	22,157	11,534
2021	608,969	547,549	29,340	28,126

Figure 4. Corn yields as impacted by grazing or and tillage treatment for 2020 and 2021.



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