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Developing Metrics for Novel Value-Added Products: The Case of Hemp in Vermont

Jane M. Kolodinsky
University of Vermont

Heather M. Darby
University of Vermont

Steven Kostell
University of Vermont

Tyler Mark
University of Kentucky

Eric D. Roy
University of Vermont

See next page for additional authors

Authors
Jane M. Kolodinsky, Heather M. Darby, Steven Kostell, Tyler Mark, Eric D. Roy, Eric Bishop von Wettberg, Hannah Lacasse, Giovanna Sassi, and Weiwei Wang

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The Case of Hemp in Vermont

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Project Team:
Jane Kolodinsky, P.I., Department of Community Development and Applied Economics (CDAE)
Heather Darby, UVM Extension and Department of Plant and Soil Science (PSS)
Steven Kostell, CDAE
Tyler Mark, University of Kentucky
Eric Roy, Rubenstein School of the Environment (RSENR)
Eric Bishop von Wettberg, PSS

Graduate Student: Hannah Lacasse
Post-doctoral Associate: Giovanna Sassi
Research Specialist: Weiwei Wang

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Abstract

Vermont ***Farm to Plate 2020*** identifies hemp as one of ten emergent agricultural products critical for Vermont's future and has made recommendations for investments in hemp research, education, feasibility, and innovation programs. These investments are essential to develop niche food, feed, fiber, and industrial products, professionals, and markets that go "beyond CBD" (VFP, 2020).

This project develops indicators for an important, value added *budding* crop in Vermont: hemp. For the purposes of this white paper, indicators are "a way to measure, indicate or point to with more or less exactness," or "something used to show the condition of a system" (Feenstra et al., 2005). We focus on the example of hemp to illustrate how emerging value-added crops contribute to sustainable food systems. We use a set of design principles to ensure the applicability of developed indicators for decision making. This framework, its processes, and measures, are transferable to any nascent crop for evaluating economic, environmental, and social sustainability.

Our objectives are to:
1. Develop a set of indicators to measure the economic, social, and environmental inputs of hemp in Vermont.
2. Identify techniques and data sources for mining hemp metrics.
3. Evaluate the hierarchical levels of mined data and transecting indicators to inform growing discussions of metric integration and forecasting agricultural food sustainability.

Our *approach is grounded* in the FAO food systems model, Doughnut Economics, which uses the UN Sustainable Development Goals as a foundation to describe "social floors" and planetary boundaries, and the concepts of seven community capitals: political, cultural, human, social, financial, built, and environmental. Our *work plan* included a two-day virtual workshop with required reading prior to the event, and involved both University researchers and stakeholders representing production, industry, finance, government, and NGOs.

We describe 35 metrics to assess the sustainability of hemp in the Vermont economy, environment and community going forward (Figure 2 and Table 1).

We also make several recommendations to move the collection of food system metrics forward. General recommendations include:

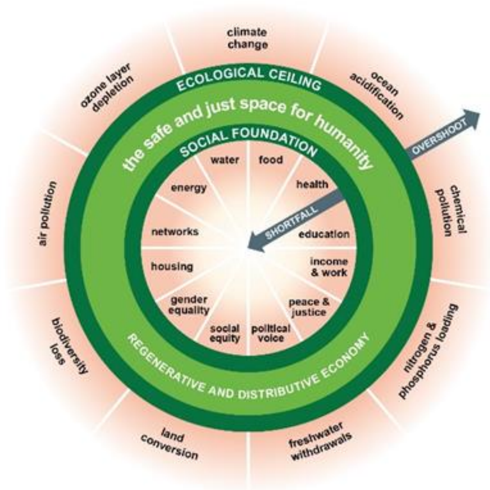
- Farmer surveys to specifically address challenges facing farmers growing a novel crop. In hemp this is particularly important, as the crop attracts many who are new to farming, and no one has been able to legally grow it at field scale in the US for the past several generations.
- Community/consumer surveys to collect data on community needs and impacts of novel value added crops (hemp)
- Collection and curation of spatial data tied to appropriate metrics
- Allocation of ARS funds for at least one data professional with skills across data types and methods, including individual, spatial, community level, etc.
- Funds to build out nutrient mass balance and soil carbon stock models for different soil types and production approaches
- The use of a grower-friendly tracking App with incentives (GoCrop)
- Development of a dashboard to easily visualize direction and degree of movement toward a desired state

We make more specific recommendations in the Appendix where each metric is described in detail.

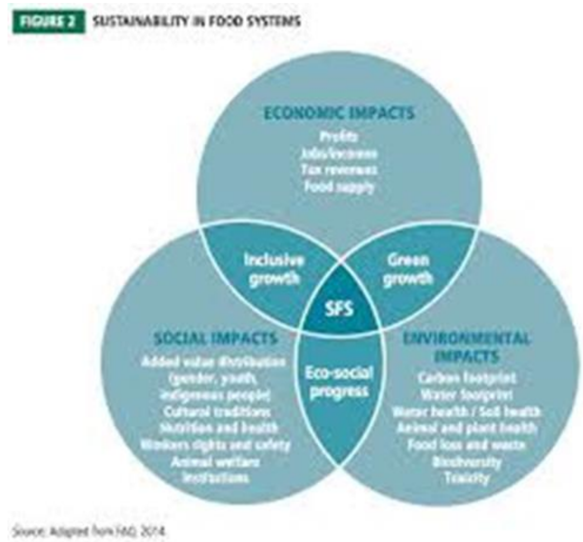
1. Summary of approach and metrics

This project uses design principles to incorporate an understanding of audience, to develop multidimensional set of indicators, that account for social floors and biophysical ceilings, that are useful for forecasting and reporting, that incorporate existing and new data, and can be directly used by a variety of stakeholders. For the purposes of this proposal, we define indicators as "a way to measure, indicate or point to with more or less exactness," or "something used to show the condition of a system" (Feenstra et al., 2005).

Our approach is grounded in both the FAO food systems model, Doughnut Economics, that uses the UN Sustainable Development Goals as a foundation to describe social floors and planetary boundaries (Nguyen, 2018; Raworth, 2017), and the community capitals concept (Flora & Flora, 2013). These are unique, yet complimentary approaches. The doughnut model is employed because it explicitly requires indicators that meet social and economic needs, while not exceeding planetary boundaries (Figure 1a). The FAO model identifies a sweet spot, but also considers there are tradeoffs between inclusive growth, green growth, and ecological progress (Figure 1b). The community capitals address well-being of communities in terms of built, cultural, financial, human, natural, political, social capitals, all of which cross reference with the FAO model and doughnut economics (Figure 1c).



1.a. Doughnut Economics



1.b. Food Systems Sustainability

1.c Community Capitals

Figures 1a, 1b, 1c. Conceptual Background Information Used for Metric Development

Our approach used the methods of the State of the State Indicators Initiative virtual workshop, UVM Gund Institute and University of Minnesota, held in April 2020 (Vermont Farm to Plate, 2019) combined with Ecotrust's Vivid Picture (Ecotrust, 2005) approach to developing indicators for Sustainable Food Systems. The goals of the workshop were:

- Agree on a framework, vision, and mission of the project;
- Engage with stakeholders to explore how an indicator system could be used in decision making, in the near term and on an ongoing basis over the longer term;
- Agree and refine a draft set of indicators; and
- Identify levels of measurement, data sources, data needs and how data might be integrated across levels of measurement.

Our underlying design principles include:

- Understand the audience for the metrics: Leaders and decision makers within state, business, NGO, and national policy making
- Indicators identify direction of movement, not "specifically what to do"
- Indicators will aim for "health in all policies." For our purposes we mean comprehensive health is social, environmental, and economic
- The indicator set will be multidimensional - not a single number
- Understanding that any set of indicators will have and will allow analysis of trade-offs and interactions among indicators
- Indicators will be based on doughnut economics to include social floors and biophysical ceilings
- Metrics can be measured continuously and are quantifiable
- The metrics should be useful for forecasting, not just reporting
- Measurable with available data
- Use simple data to get started and repeat easily
- Use data stakeholders are familiar with
- The metrics should be directly useful to key stakeholders
- Designed in careful collaboration with stakeholders
- Easy to interpret and communicate

Figure 2 provides a visual overview of how the chosen metrics network within both the community capitals framework and the FAO model of environment, social, and economic factors.

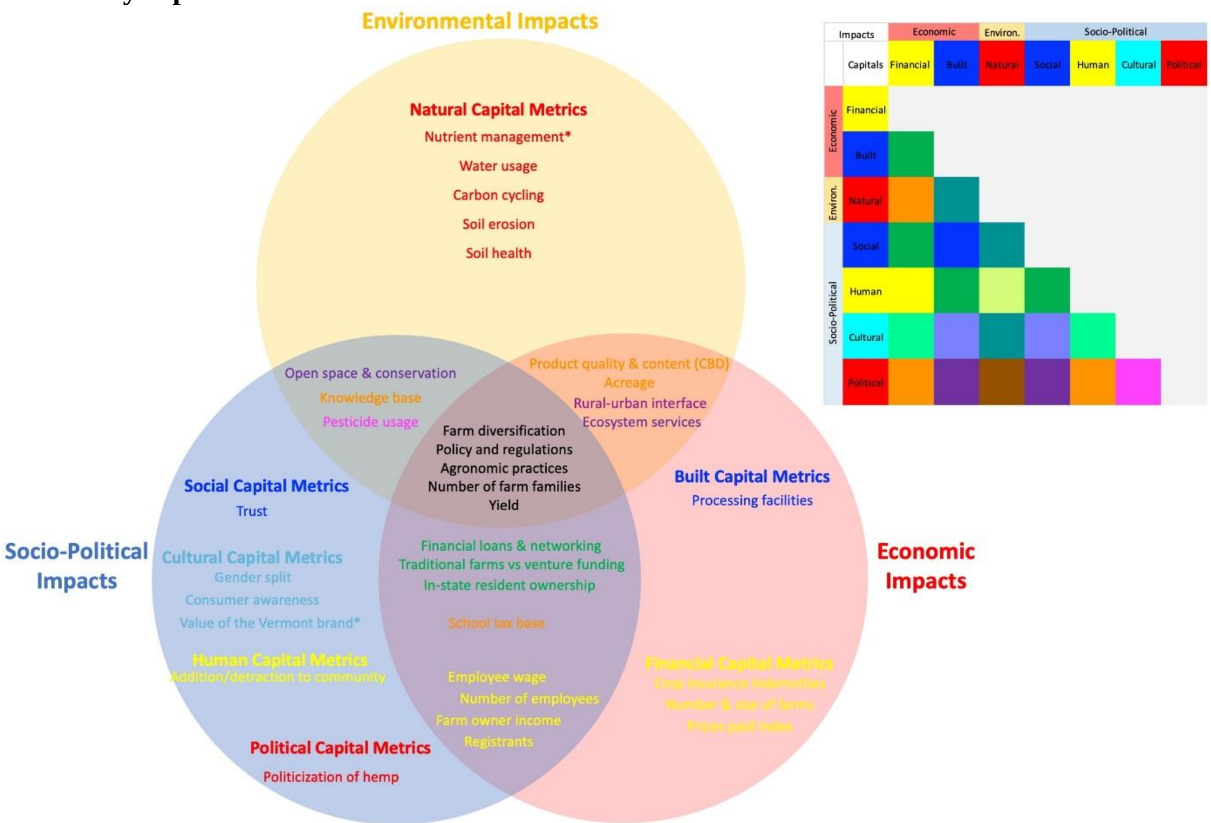
2. Background on chosen metrics

We agree with the Vivid Picture project approach (Ecotrust, 2005) and take the point of view that indicators are useless if they are not used. Our stakeholders supplied input and understood and support the set of indicators selected. Our team met several times over the Fall semester, had "homework" in their area of expertise, and supplied information and feedback on the data and content as well as the availability of data sources. Our team reviewed the indicator set and finalized our proposed set.

Our full set of metrics is presented as Table 1. However, we expect that, in the end, a smaller number of metrics will prove both more manageable and more easily applied across distinct aspects of how small and medium farms engage the food system.

We expand upon each metric in the Appendix as its own stand-alone, publishable unit (such as Extension fact sheets) and present arguments for its usefulness of evaluating the sustainability of small and medium-sized farms within the context of the hemp food system. For each of the 35 chosen metrics we discuss their relevance as assessment tools and for various stakeholders, their merits, and limitations with respect to the trends we expect them to reveal. In addition, we report on the availability of data across hierarchical categories (individual farm, town, county, state, region), their sources and how we intend to collect missing data that is required for useful analysis. Here, we have also compiled a bulleted list of recommendations with which to proceed into the subsequent phase of our Team's efforts.

Figure 2. Integrating hemp metrics to evaluate the sustainability of small-to medium-sized farm community capitals.



3. Methods

Summer 2020 Hemp Stakeholder Meeting

In August 2020, the University of Vermont ARS Hemp Metrics team (UVM-ARS-HM) hosted a two-day workshop to discuss the indicators and metrics that would be the most beneficial to the hemp industry. Participants included hemp industry stakeholders in the areas of policy, production, processors, and retail sectors, as well as faculty, staff, and students from UVM and the University of Kentucky. Prior to the workshop, the ARS Hemp team identified a list of 76 metrics focusing on environment, economic, and social components of the FAO model (Nguyen, 2018). This list was not sent to stakeholders prior to the workshop but used as a reference for discussion. In the first day of the workshop, stakeholders were invited to discuss the indicators that are needed for decision making and that lie within the three areas of focus - economy, environment, and society. Broad discussions were held about the diverse types of information that would help make decisions, followed by breakout group discussions to specifically target the three areas of concern: economics/production, environment or society/community. Stakeholders were assigned to a group based on their area of expertise and the need to balance the number of participants in each group. Within each breakout group, stakeholders were asked about the metrics used in hemp that they currently use to better understand the benefits or detractions within their given focus area and which metrics might be of use to them that are not currently available. In the second day of the workshop, the ARS team compiled the responses from the stakeholders and compared them to the list of metrics the team developed prior to the workshop.

Virtual team discussions and consensus

Using an iterative process of online discussions and data gathering over the Fall 2020 semester, we agreed upon a total of 35 metrics to be of priority for Vermont hemp stakeholders. Our final set of metrics and their interactions are presented as Figure 2. The roadmap to developing those metrices and the questions used to guide the discussion ae presented as Figure 3.

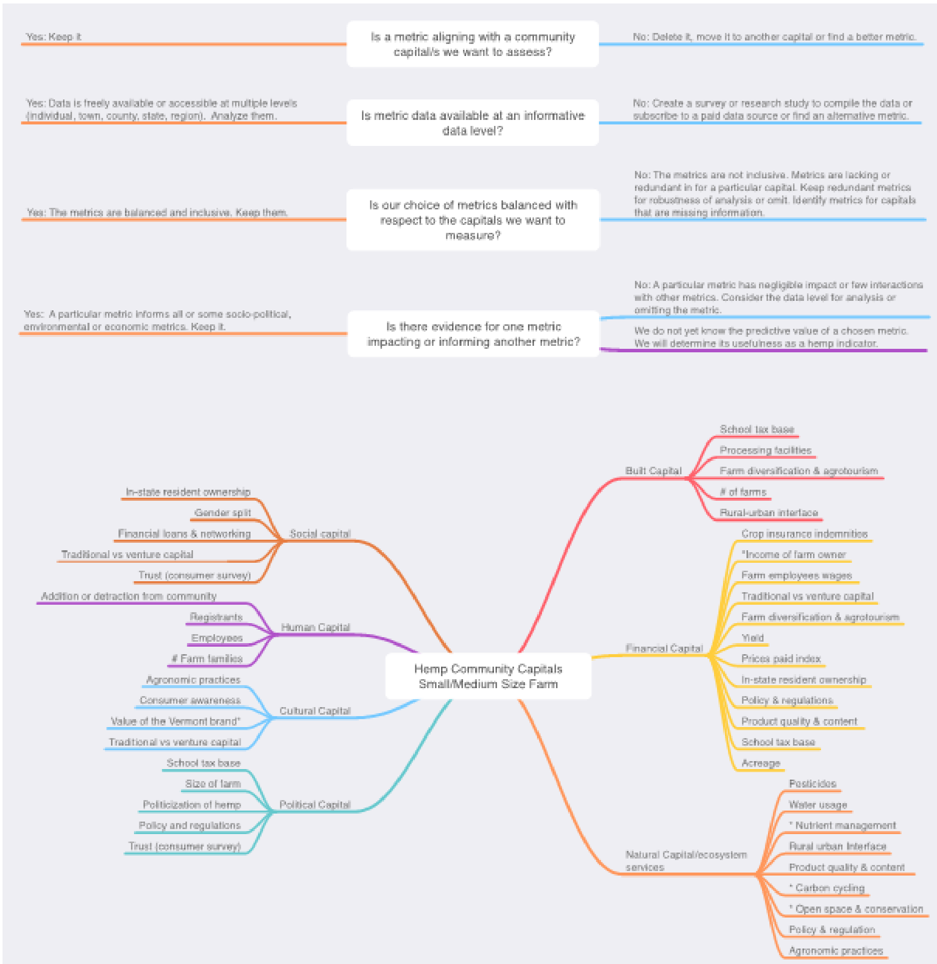
Table 1. Indicators selected for measuring the economic, environmental, and socio-political sustainability of small-medium hemp farms, availability of data at multiple hierarchical levels and sources for the chosen metrics. Individual, town, county, state, region.

Indicators (35)	Data Level					Source
Economic Metrics (12)						
Acreage			X			Farm Service Agency, NASS (long-term)
Yield (planted vs. Harvested)	X		X			VAAFM, NASS (long-term) & USDA-RMA, need survey
Number and size of farms	X	X	X	X		VAAFM and will need surveys
Product quality and chemical content	X					VDA & NASS (long-term)
Crop insurance indemnities			X			USDA-RMA
Prices paid index				X		AMS production survey & NASS
Registrants	X	X	X	X		VDA
Farm owner income	X					AMS production survey & ARMS
Number of employees						Will need surveys
Employee wage	X					AMS production survey & ARMS
Farm diversification						Will need surveys
Processing facilities						VAAFM, industry reports
Environmental Metrics (10)						
Nutrient management	X					Will need surveys & measurements
Water usage						Will need surveys
Carbon cycling	X					Will need surveys & measurements
Soil erosion	X					Need research
Soil health	X					Need research
Open space and conservation	X	X	X			Registration info from S. Smith and GIS
Rural-urban interface						Will need surveys, GIS
Agronomic practices	X					Will need surveys
Ecosystems services	X	X	X			Inferred from others, will need research, surveys
Pesticide usage						VAAFM and will need surveys
Socio-Political Metrics (13)						
Consumer awareness	X	X	X			Will need surveys
Politicization of hemp			X			County voting records
Gender split in farm ownership				X		Stephanie Smith
In/out of state ownership				X		VT Hemp registry
Number of farm families						Will need surveys
School tax base		X	X	X		Town tax records
Policy and regulations						VAAFM, 2018 Farm Bill
Trust						Will need surveys
Value of the Vermont brand						Will need surveys
Addition/detraction to community						Will need surveys, research newspapers, media
Knowledge base						Will need surveys
Financial loans and networking						Will need surveys, research lenders
Traditional farms vs venture funding						Will need surveys, research funders

KEY

individual
town
county
state
regional

Figure 3. Discussion and decision prompts for guiding our selection of metrics for the hemp community.



4. Results and Implications

a. Selected metrics

The selected 35 metrics are expanded on in the Appendix and presented in Figure 1 and Table 1, above.

b. What data is necessary

We discuss the data necessary for each metric in the Appendix. In our future directions section, as well as in each metric in our Appendix, we advocate for the need for more producer and consumer survey data. Some of this we expect to come as the 2018 Farm Bill brings more state-to-state consistency to hemp regulations, and as USDA NASS begins to collect data on hemp.

c. How to store/document and track data

Because of hemp's unique legal history, it has fewer data available in the public realm than many other commodity crops. The regulatory environment for hemp also affects how states or other municipalities handle data on things like registrations.

d. How could this be measured/replicated?

We expand on measures and replications in the Appendix, for each metric.

e. What challenges they anticipate
We expect that data availability will be a challenge, as will levels of measurement. For example, for data that are available, some is collected on the individual level, while other data are collected on a community, county, state, or even regional level. In addition, for new data collection that require individual/household/farm level/retail establishment level responses, trust in who is collecting information and how it will be used is of particular concern. This is especially true of hemp, as regulations have not been finalized.

f. Other metrics that should be considered
Our list of 35 metrics is purposefully expansive, and we expect that when the white paper groups are convened, the list may be honed. If requested, our team can supply the original 75 metrics that we brainstormed, but this number and variety seem excessive for this final report.

5. Future implications and recommendations
Below we collate all of the recommendations made individually in the Appendix which describes and provides background on each metric.

- Determine the influence of acreage, yield and optimal planting density (plants/acre) metrics for each hemp target market (grain, fiber, or oil production) of selected cultivars for our climate through farmer surveys.
- Assess the social impact of empowering individual growers to use whole plant parts and report usage of parts per acreage of output (fine scale), harvested and sold.
- Gather more detailed yield data by product subtype per individual grower through a farmer survey or potentially from commercial (subscription required) production reports.
- Administer a survey to identify growers that also process hemp, provide unique ID's to cross reference from older lists of growers and processors, and identify overall farm size compared to cultivated acres of hemp or other crops.
- We recommend biological research in genetic and genomic tools to improve essential oil to THC ratios, maximize cannabinoid yields, increase stability and uniformity, improved pest resistance and regional adaptation. Additionally, webinars or brief info sheets for growers on genetic relatedness of crop varieties, concepts of genetic modification (both for and against), better seed production, decreased costs and environmental impact and corporate control of genetic resources.
- Identify data by survey then compare the number of policies written vs the number of hemp registrants.
- Begin to collect price data once USDA begins collecting it.
- Obtain consistent data and subtypes across years <u>for registrants</u> by using person-person (virtual or live survey) or an entry system that does not allow for blank entries (NA or 0 is more informative than blanks) or multiple-choice ranges.
- A producer survey is needed to collect hemp-specific income estimates.
- Develop a survey of farmers to collect information on wages and how they are paid, whether and which benefits are offered, and whether employment if full time, part time, or seasonal.
- A grower survey is needed to address questions about farm diversification activities.
- Coordinating state registries and establishing reporting mechanisms for facilities would reflect the market strengths and help to identify material dependent manufacturing industries. The development of regional processing facilities could have a positive impact on rural employment opportunities and spur regional manufacturing enterprises. Clear and explicit protocols for traceability, quality control, ensuring food safety and removing between the growers: processors: vendors is paramount as the local industry plays catch up with the popular demand for products.

- We recommend further streamlining of the data collection process for whole-farm nutrient mass balance calculations on hemp farms and stakeholder engagement to aid interpretation of mass balance results. We recommend generating the data necessary to include hemp in the FarmPREP (APEX) model being used in the Vermont Pay-for-Phosphorus Program, including hemp crop growth parameters, hemp agronomic practices, crop rotations, operation schedules, and other key information to model water quality goals across multiple fields, aggregated to the farm scale.
- Survey data on hemp water usage are needed. We recommend that the AMS production survey include information on hemp water use in Vermont. Creation of a model to assess water use in hemp production, such as The Cool Farm Tool, may be a useful resource for growers (Hillier et al. 2011).
- In Vermont, we need carbon data for soils analysis and modeling in hemp production across a range of soil types, and across any variation in production systems. This recommendation would occur in parallel to work on nutrient management and mass balance (above).
- We recommend that erosion reports be included in regular surveys of farmers, to determine if hemp practices are causing erosion to increase.
- As hemp production expands and the industry matures, collecting on-going soil data from farms will be important to helping guide farmers to maintain aspects of soil health, from nutrient levels to soil carbon.
- There is a need for more agronomic research, building on the foundation laid by Professor Darby, that focuses on development of agronomic practices that optimize crop productivity *and* environment needs to be prioritized. Optimizing resources and expediting research is critical as the industry grows quickly with or without this information. We recommend that the AMS production survey incorporate data on the production practices being implemented by hemp farmers, including crop rotations, cover crops, reduced tillage, nutrient management, soil testing, water buffers, crop diversification and scouting.
- Further studies on hemp diseases and control can spur the development of integrated pest management approaches to reduce disease and cost. In addition, plant breeding programs are necessary for industry success. Pesticide usage could be a self-reported metric through farmer surveys. Consumer survey data could reveal attitudes toward pesticide-treated products, as well as farmers' use of off-label products.
- An understanding of market requirements and developing industry standards for quality can help set Vermont's priorities to the highest level in order to garner a high value share.
- We recommend examining open space at the rural-urban/suburban interface, to determine whether hemp farms in Chittenden country or other more urban areas are potentially contributing to the preservation of open space in peri-urban areas where development has most threatened open space and the value it provides. Hemp monoculture will eventually lead to yield decline, as it does for all crops. Overhead imagery over time can provide some insight into possible rotations.
- We think this metric deserves further consideration to determine how well it connects to measures of social sustainability. With registry data, we can assess whether hemp production is closer to more urbanized areas near Burlington or elsewhere in Vermont.
- Data on purchasing patterns and demand for *all* categories of hemp products should be collected in order to fully understand consumer awareness and perception.
- Data on county and state voting regarding hemp should be collected, as well as measure of the percent of population registered by party in a county. Identification of the political party of the state rep and senator will be necessary for analysis.
- Demographic data collection in grower and producer surveys should be prioritized. Including qualitative data collection to supply broader understanding of underrepresented groups is critical.

- We recommend that a yearly survey to farmers include a question regarding residency.
- We recommend that any survey of farmers to also collect information on whether the operation is a family farm.
- Tax data should be used along with other Socio-political metrics to gain a better understanding of community context.
- Limited data is available about policy and regulation as state guidelines have not been published due to changes in the 2018 Farm Bill.
- Annual citizen and producer survey questions regarding trust in industrial hemp operations, production processes, and institutions are needed.
- There is currently no data available about the value of the Vermont brand associated with hemp.
- There is no evidence that the odor impacts physical health negatively. In data collected by the Center for Rural Studies in 2020, some respondents indicated that they were opposed to hemp production in the state due to its smell.
- We recommend including questions that capture the extent and sources of knowledge base on statewide hemp farmer survey.

6. Biographical sketches

Heather Darby is an agronomic and soils specialist for the University of Vermont Extension. Being raised on a dairy farm in Northwestern Vermont has also allowed her to play an active role in all aspects of dairy farming as well as gain knowledge of the land and create an awareness of the demanding work and dedication required to operate a farm. These practical experiences complemented by her education have focused her attention towards sustainable agriculture and promotion of environmental stewardship of the land. Heather is involved with implementing many research and outreach programs in the areas of fuel, forage and grain production systems in New England. Outreach programs have focused on delivering on-farm education in the areas of soil health, nutrient management, organic grain and forage production, and oilseed production. Research has focused on traditional and niche crop variety trials, weed management strategies and cropping systems development.

Eric Bishop-von Wettberg is an associate professor in the Department of Plant and Soil Science at UVM where he leads the Crop Genetic Heritage laboratory. He is also a fellow of the Gund Institute and the director of the Food Systems graduate program. To create an agricultural system more resilient against climate change, the Crop Genetic Heritage laboratory aims to 1. protect and enhance the diversity of crops grown in Vermont to improve their capacity to handle novel climatic conditions and 2. Investigate variation in how crops sequester carbon into soils. Von Wettberg and colleagues are focused on hemp as a new crop for Vermont due to its considerable genetic variation among market classes and unique system for sexual reproduction, and for its capacity to sequester substantial amounts of carbon.

Jane Kolodinsky is professor and chair of the Community Development and Applied Economics at UVM and the Director of the Center for Rural Studies. She is also a fellow of the Gund Institute. Her work focuses on a system approach to rural economic vitality. Kolodinsky currently leads this metrics project and is P.D. on a national level USDA NIFA Foundational project on the Economic Impact of the Hemp Industry, with colleagues in Vermont, Kentucky, and Colorado.

Steven Kostell is an Assistant Professor in the Department of Community Development and Applied Economics at the University of Vermont and leads the UVM BioFiber Lab. The lab focuses on developing sustainable, compostable, and recyclable bioproduct prototypes; demonstrate the potential for agricultural fibers as value-added material stream; and model at-scale manufacturing opportunities, employing regenerative circular design principles. Kostell is the P.D. on a transdisciplinary USDA NIFA REEU, investigating the agricultural transition toward industrial hemp production.

Hannah Lacasse is a graduate student in the Department of Community Development and Applied Economics at UVM. Her research focuses on the economic implications of hemp in Vermont, particularly consumer behavior and preference for hemp products and the economic impacts of hemp production.

Eric Roy is an Assistant Professor at UVM with appointments in the Rubenstein School of Environment and Natural Resources (primary) and the Department of Civil and Environmental Engineering (secondary). He is also a Fellow of the Gund Institute for Environment. Dr. Roy's research team works at the interface of ecology and engineering to support nutrient management efforts and related sustainability goals, focusing on water, food systems, and resource management. This work covers three important themes in nutrient stewardship (nutrient use efficiency in food systems, resource recovery and reuse, and nature-based solutions/green infrastructure), as well as related carbon cycling.

Giovanna Sassi is a postdoctoral researcher with the department of Plant and Soil Science at the University of Vermont in the Crop Genetic Heritage laboratory under the mentorship of Dr. Eric Bishop von Wettberg. Here, she studies the genetic basis of hops and hemp disease resistance, metabolite synthesis and diversity between domesticated and wild plant populations using comparative bioinformatics, pathogenicity assays, tissue culture and field assessments with aims to improve crop sustainability through breeding. Dr. Sassi is interested in the evolution of plant-microbe interactions and the contributions of root symbioses to regenerative agriculture. Giovanna has drafted the outline for this whitepaper, gathered visuals to support the text and assisted in writing. gsassi@uvm.edu.

Weiwei Wang is a Research Specialist at the Center for Rural Studies (CRS) and graduate student in the Department of Community Development and Applied Economics at the University of Vermont. Her work with CRS includes work with consumer and producer behavior in direct-to-consumer agricultural markets, agritourism, hemp, as well as evaluation and survey research. Her academic research focus is on the food systems, with focus on direct-to-consumer markets and accessibility. Her contribution to this white paper includes writing and logistical support.

Tyler Mark is an associate professor of production economics in the Department of Agricultural Economics at the University of Kentucky and Director of Graduate Studies. His applied research interests include hemp economics, broadband availability in rural areas, precision agriculture, and precision dairy. Current projects include the economic impact of hemp production, hemp cost of production, hemp consumer preferences, hemp land-use change and pricing of essential oils, broadband internet's impact on precision agriculture data transmission, and the development of the Kentucky's hemp economy.

7. Appendices

Economic Metrics

1. Acreage

Acreage is a metric that allows for the measurement of land area used. The units of hemp production, measured in acres or reported as $/sq in the case of indoor hemp production, is typically characterized for each hemp target market (grain, fiber, essential oils).

Stakeholder relevance

Hemp, unlike any other crop produced in the United States, requires a state license to grow or process. Therefore, the distinction between diverse types of hemp acreage reported; planned/licensed, planted, harvested, and sold is pertinent. For the hemp industry, currently, the numerical value of *harvested* acres is the key informative indicator for evaluating growth in production but, as the agricultural transition continues, we may need to consider other types of acreage reporting.

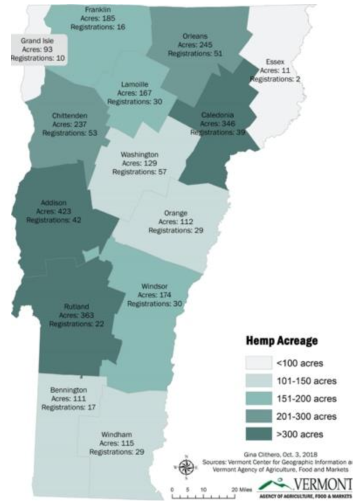


Figure A1. Total acreage cultivated per county and registrants for the state of Vermont in 2018.

Sustainability, community capitals and interdependence of metrics

Acreage contributes to both Financial and Natural community capitals (Flora & Flora, 2013) since the availability of arable land (natural resource or greenhouse) along with the presence of resources required to farm it appear inextricably linked. In addition, ***acreage,*** directly informs the metric of ***yield*** that itself is influenced by ***planting density*** (plants/acre) (OMAFRA, 2017). The interaction of metrics; ***acreage, yield*** and **planting density** may be influenced by the choice of hemp ***cultivars*** (Lisson & Mendham, 2000).

Merits and limitations

The usefulness of acreage estimates, as indicators of the economic sustainability of hemp, lies in the ability to compare discrete numerical values of land-use for hemp production across geographies, target products and time. However, the acreage units reported often represent the amount of hemp *licensed* for production rather than the acres *harvested* resulting in an inflation of this metric thereby limiting its reliability and accuracy as a decision-making tool (Mark et al., 2020).

Data levels and availability

The Hemp Registry through the Vermont Agency of Agriculture reports the percentage of land area planted to hemp compared to other crops in the state (Figure A1) (VAAFM, 2020). As a function of acreage planted and target product, this metric would be most useful for production comparisons relative to other states. Currently, acreage data is available from the collections of the USDA-FSA but is to be interpreted with caution as, to date, not all hemp producers must report their acreages under the 2018 Farm Bill (Mark et al., 2020). Consequently, the available federal data underestimates hemp acreage and may mislead analyses and misinform decisions until requirement for reporting hemp acreage becomes law on September 30, 2021. Other sources of hemp acreage data are industry journals, associations or private analysis firms that require a subscription or paid membership to access or government resources from other nations (Kim & Mark, 2018; New Frontier Data, 2020).

Recommendation

Determine the influence of acreage, yield and optimal planting density (plants/acre) metrics for each hemp target market (grain, fiber, or oil production) of selected cultivars for our climate through farmer surveys. Assess the social impact of empowering individual growers to use whole plant parts and report usage of parts per acreage of output (fine scale), harvested and sold.

2. Yield

Yield is a metric that specifies the numerical quantity of harvested product, in weight or volume, expressed per unit of planted land or individual plant and implicitly encompasses the inputs necessary, such as seeds or fertilizer, for hemp growth. As such, yield is a metric that describes the ***efficiency*** of cultivation (Mills, 2012). The units for hemp yields are distinguished according to the type of end-product or by-product formed; fiber hemp in tons/acre, grain hemp in lbs./acre, essential oil hemp in lbs./plant, lbs./acre, lbs. processed or % cannabidiol (CBD) in mg/100 gram of dry inflorescence (Vuerich et al., 2019).

Stakeholder relevance

Yield helps stakeholders discern whether there are sufficient outputs of materials for processing to qualify the inputs required to grow them. An inverse relationship of high outputs to low inputs is the desirable outcome and over a trajectory of time. Hemp by-products could have added value for fiber, fuel, or biochar with minimal further inputs or processing. Whereas hemp essential oils may obtain higher prices per unit acre if further processed into massage oils, teas, or edible dressings, the costs associated with refinement and testing for a higher quality product may become prohibitive.

Sustainability, community capitals and interdependence

We consider *yield* a natural capital, as it is partially determined by the natural fertility of a soil and the suitability of a climate. As management (agronomic practices, pesticides, selection of genetics, etc.) influences yield as well, it is also connected to social capital (how farmers chose to manage) and built capital (access to inputs to raise yield, such as tiled drainage or irrigation).

Merits and limitations

Yield is a valuable indicator for gauging the economic sustainability of hemp as it supplies a measure of the ***existing*** material that is available for further processing either as end- or by-products. However, yield as a metric can vary widely by cultivar planted or due to uncontrollable biotic or abiotic factors that influence a plant's composition, making it challenging to maintain consistency across comparisons hemp yields.

Data levels and availability

Yield data is available as ***lbs. processed annually*** from the Vermont Agency of Agriculture and reported as the sum by **town.** This data source ***does not*** provide a numerical yield value for each subtype of hemp end-product or by-product but a qualitative "true or false" entry by town. Currently, we have sparse data for yield from university trials and some state level data collected by the AMS production survey (Darby et al., 2017a; Darby et al., 2017b; Darby et al., 2017c; Mark et al., 2020; Schluttenhofer & Yuan, 2017; The Jacobsen, 2020). In the future, the USDA Agriculture Statistics Service will be collecting state average data for yields of hemp grain, fiber, and flower/biomass.

Recommendation

Gather more detailed yield data by product subtype per individual grower through a farmer survey or potentially from commercial (subscription required) production reports.

Table 1. Hemp varieties grown, Alburgh, VT, 2016.

Variety	26-May Yield lbs ac^{-1}	2-Jun Yield lbs ac^{-1}	12-Jun Yield lbs ac^{-1}	17-Jun Yield lbs ac^{-1}	Seed company	Days to maturity
Anka	2200	689 †	391	473	Valley Bio Limited	110
CFX-2	1860	529 †	421	419	Hemp Genetics International	100-110
CRS-1	2200	598†	478	421	Hemp Genetics International	100-110
Grandi	1550	336	317	380	Hemp Genetics International	100-110
Katani	1260	365	307	405	Hemp Genetics International	100-110
Canda	2160	**751†**	482	623	Parkland Industrial Hemp Growers	100-120
Delores	1720	721†	428	394	Parkland Industrial Hemp Growers	100-120
Full sun	---	609 †	430	---	Full Sun Company	---
Fedora	---	---	---	836‡	AssoCanapa	120
Felina	---	---	---	888 ‡	AssoCanapa	120
Futura	---	---	---	**904** ‡	AssoCanapa	140
USO-31	---	---	---	332	AssoCanapa	90-100
LSD (0.10)	NS	225	NS	169		
Trial mean	1850	575	407	552		

Varieties with a symbol (†, ‡) did not perform statistically worse than the top performing treatment (p=0.10) for that planting date. Treatments in bold were top performers for the given variable.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Figure A2. Hemp yields expressed as lbs per acre for UVM 2016 Hemp Trial.

3. Number and size of farm

The number of farms in a region or state along with their size in acreage per farm is a metric that describes the density of hemp operations in a location and may reveal growth trends or interest for the crop over time. While the USDA definition of farm size focuses on the annual income drawn by each operation, we focus on the acreage per farm to better understand if each operation is concentrated or dispersed across various locations (USDA & NASS, 2020).

Stakeholder relevance

This metric suggests the potential or scale of production possible for a given area, competition or saturation of a region, the economic impact of hemp activities to the local economy, and whether local labor is available.

Sustainability, community capitals and interdependence of metrics

We consider the ***number and size of farms*** as indicators of financial and political community capitals since a change in these metrics impacts a community's power to acquire resources either through financial establishments or elected officials (Flora & Flora, 2013). To add, the ***number and size of farms*** can be influenced by a second metric, ***in/out of state ownership,*** as out-of-state owners may not have as much interest in supporting local economy or hiring from within community than an in-state owner (OMAFRA 2017). With respect to the sustainability of the Hemp Food System, we posit that the ***number and size of farms*** and ***ownership,*** as metrics, inform us about inclusive community growth by describing ***economic development*** (tax revenue, jobs) and tethered to **socio-political foundations** (voting power, reducing inequality) (Nguyen, 2018).

Merits and limitations

Understanding the number and size of hemp farms contributes to the social and economic impact of the farm at the local, regional, and state-wide levels. Moreover, there are environmental and social externalities that may be yet unexplored depending on the physical size of the farm operation, as well as the number of operations (Crowe, 2019). To date, processor and grower information are available separately in data sheets and there is no way to identify or match whether a grower is also a processor.

Data levels and availability

Data is available for the ***number of farms*** from Vermont Agency of Agriculture and is reported as "individual business" therefore making it possible to calculate town, county, and state data levels**.** This data source ***does not*** provide a numerical value for overall ***size of farm*** but does describe hemp acres in cultivation or indoor square feet.

Recommendation

Administer a survey to identify growers that also process hemp, provide unique ID's to cross reference from older lists of growers and processors, and identify overall farm size compared to cultivated acres of hemp or other crops.

4. Product quality and chemical content

Product quality and the chemical content of hemp are metrics that guide the price and interest of a particular hemp product (Dryburgh et al., 2018; Schluttenhofer & Yuan, 2017). For example, hemp grain that is high in weight, protein, and oil content in desirable and must be free of contaminants as it enters the food system (Dryburgh et al., 2018; Shahzad, 2012). Fiber hemp quality is evaluated through fiber length, tensile strength, and fiber width (Salentijn, Petit & Trindade, 2019; Shahzad, 2012). For essential oil or medicinal hemp, the concentration of CBD and the ratio of CBD relative to other cannabinoids in relevant for health care providers, consumers, and regulatory bodies (Pratt, 2019).

Stakeholder relevance

Measurements of hemp oil or protein content, presence of contaminants, fiber lengths and strengths help determine whether a variety or a particular harvest is suitable for its intended purpose (seed, fiber, essential oil) or can be repurposed for other uses (mulch, building materials, compost) (Schluttenhofer & Yuan, 2017). In other words, this data provides a measure of whether the product quality meets market requirements set by the industry or quality parameters set by an individual buyer. Most buyers have minimum quality and content requirements that follow state/federal regulatory requirements.

Sustainability, community capitals and interdependence of metrics

We consider chemical composition a natural capital, given how environmental (climatic and soil factors) interact with plant genetics to generate the secondary chemistry profile. But the chemical composition impacts other capitals, particularly the financial, economic, and social capitals because of how material exceeding the THC threshold is regulated and must be destroyed.

Merits and limitations

Product quality and chemical content, in addition to yield, are critical variables in determining value and optimized protocols for their measurement are well established (Dryburgh et al., 2018). The numerical values are expressed in units or % by weight of analyzed tissue and therefore comparable across many conditions, locations, seasons, and examiners. However, fiber and grain quality for various markets has been set in countries other than the USA and, although parameters could be secured from these locations, we need to establish our own state and national requirements adapted from our climate, conditions and yields from currently unavailable long-term studies.

Data levels and availability

To date, each state reports accounts of THC threshold non-compliance and its percentage found from registered farms as a condition of registry. Locally, Bia Diagnostic's in Colchester posts detailed summaries on their website of cannabinoid chemistry and content, mold spores, toxins and microbial counts as a service to growers who have paid for their analyses and want to provide a public certification of purity for their harvest to potential buyers. This is the only resource in the state that can perform analytical certification and reporting.

Recommendation

We recommend biological research in genetic and genomic tools to improve essential oil to THC ratios, maximize cannabinoid yields, increase stability and uniformity, improved pest resistance and regional adaptation. Additionally, webinars or brief info sheets for growers on genetic relatedness of crop varieties, concepts of genetic modification (both for and against), better seed production, decreased costs and environmental impact and corporate control of genetic resources.

5. Crop insurance indemnities

U.S. hemp growers currently have access to 3 risk-management programs offered by the USDA that offer financial protection against crop losses; these are the Multi-Peril Crop Insurance (MPCI), Whole Farm Revenue Protection (WFRP) and the Noninsured Crop Disaster Assistance Program (NAP) regardless of hemp crop type (seed, fiber, flower/essential oil) (USDA, 2020). Crop insurance indemnities (CIIs), as a metric of risk and sustainability, are national and regional estimates of a comprehensive form of insurance compensation for loss. For hemp, the crop insurance indemnities in the U.S. are reported in $ amounts by county from the USDA Risk Management Agency. In 2020, there was a total of 695 MPCI policies written that insured 24,713 acres of production with $32,932,309 in liabilities covered, with $4,329,225 in premiums paid and total indemnities of $10,307,012 for the U.S. (USDA, 2020).

Stakeholder relevance

This metric supplies an indicator of minimal risk management for hemp producers. CIIs are one of the few risk management strategies available to hemp producers that provides protection from crop loss. We expect, with the current carbon input models, that the increase in global temperatures and extremes in climate events will persist for decades to come and subsequently, so will the $ value of CII's metric (Crane-Droesch et al., 2019). Furthermore, a select few hemp varieties, grown in containers starting this year 2021, will be further insurable by both the Nursery Value Select pilot and Nursery crop insurance program, driving up the overall $ value of CII's metric for future years.

Sustainability, community capitals and interdependence of metrics

The current research analyses on agricultural risk management and climate change show a robust correlation in the rise in the rates of greenhouse gas emissions (***carbon cycling metric***) with the metric of crop insurance indemnities (CII's) under both moderate and severe emissions scenarios with a cost increase of 3.5 or 22%, respectively (Crane-Droesch et al., 2019. In terms of Hemp Food System Sustainability and the framework of Community Capitals, we predict that a hemp-specific ***CII***'s metric, as an indicator of financial capital, intersects with metrics of ***social*** (minority, trust) and ***political*** community capitals (***policy-regulation***) and is vastly influenced by Natural or Ecosystem inputs like ***climate data, carbon cycling and agronomic practices metrics***.

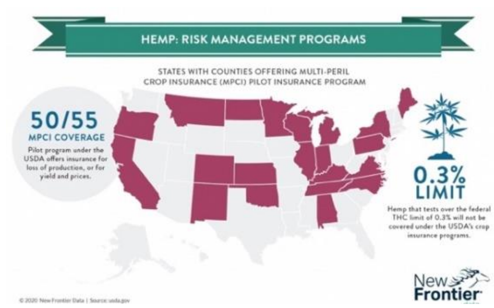


Figure A5. U.S. states offering MPCI programs for hemp in 2020.

Merits and limitations

CII's are now based on acreage planted. MPCI is not available in all states yet but will be in the future. Its continued expansion will help to stabilize the market.

NAP (non-federally insured crops) through FSA -- a substitute for RMA should be covering hemp in Vermont. FSA also has the NAP and RMA have WFRP programs that could also pay on hemp. We would need to evaluate whether the observed correlation of greenhouse emissions (***carbon cycling metric)*** and ***CII***'s metrics holds true for future hemp harvests in Vermont and the nation. ***Owners of small farms*** in the USA from minority and socially disadvantaged backgrounds often decline participation in federal ***crop insurance programs*** or do not buy insurance (Dismukes, et al. 1997). We do not have the data, yet, in Vermont to suggest whether the metric of CIIs or policies purchased align with the socio-cultural information of hemp growers, but it would help us clarify priorities of support for Vermont hemp farmers.

Data levels and availability

USDA-RMA will break this out by crop and state. Currently Vermont is not part of the MPCI crop insurance from RMA. Crop insurance programs (federally) keep track of crop loss. RMA collects the data. Currently 21 states are included in the MCPI pilot program and more are being added for 2021, VT is not included in pilot program.

Recommendation

We recommend comparing the number of policies written vs the number of hemp registrants.

6. Prices paid index

The ***prices paid index (PPI)***, expressed in % conveys the economic pressure confronting growers and processors and their economic sustainability. This metric is based on yearly sales information collected from agribusinesses by the USDA's National Agricultural Statistics Service (NASS) for 450 agricultural inputs paid for by producers relative to those prices paid during the 1990-1992 period (NASS, 2020). For instance, an ***index*** of 90% means that there was a 10% decrease in prices received by producers than paid inputs compared to the 1990-1992 ratio set at 100%. PPI may be considered on an annual basis or may be measured as an average (or sliding window) of several years' sales.

Stakeholder relevance

The economic sustainability of a hemp farm depends upon its profitability, and the elements that compose the PPI represent actual costs that must be covered by sales, in the current year or over a longer period. The ***PPI helps*** to assess the viability or sustainability of a grower within the hemp community by comparing it against the income derived from hemp activities that must exceed inputs if a non-subsidized farm is to be viable (Zulauf & Rettig, 2013. This metric informs us about the profitability of a crop and may determine whether a grower can sustain their presence in the community of producers. PPI may also reflect the perceived degree of competition for product in the marketplace, with high values consistent with unmet demand (a seller's market), and low values indicative of market saturation (buyers' market) compared to the reference period.

Sustainability, community capitals and interdependence of metrics

Within the set of Community Capitals, PPI incorporates most of the items contained within the Financial Capital group and interacts with others such as the Social Community Capital group that includes investors and banks through their loans, and Human Capital that considers farm employees and families. ***PPI*** falls under ***financial community capitals***, and directly describes the impacts on a ***farmer's income*** and their ***employee's wages***, shows whether expansion of ***acreage*** is possible, and affects the local community through ***school and other taxes***. The ***PPI*** also interacts with other metrics of ***Social Capital*** by permitting sustained ***employment and wages for farm workers***, farm ***ownership*** and debt repayment; ***Human Capital*** through supplying jobs for ***workers and family members***; and ***Cultural Capital*** in bolstering the value of the ***Vermont Brand***.

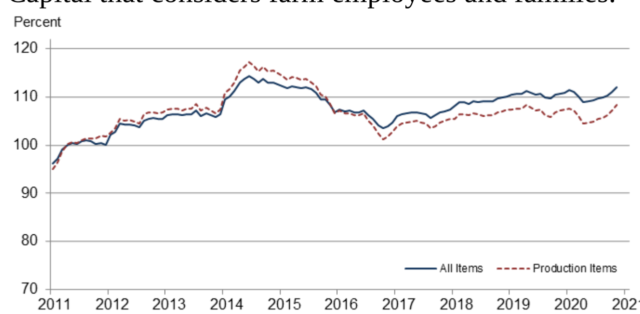


Figure A6. U.S. paid indexes by month for all items and production items: 2011=100 (NASS, 2020).

Merits and limitations

The PPI metric supplies a barometer for how input costs have changed overtime and across regions and helps growers and their advisors consider the myriad of expenses that affect a crop value, and that should be considered in deciding market price. However, though the PPI Metric is well established, its values for hemp production are not as well established as for older and more established crops.

Data levels and availability

A starting point for this analysis is the AMS production cost survey being conducted in 2021. Long-term producer price index information will be available through USDA-ERS and the Agricultural Resource Management Survey. Regional price information for clones and seed prices are available through PanXchange and HempBenchmarks.

Recommendation

We recommend collecting price data once USDA begins hemp-specific data collection.

7. Registrants
Registrants, as a metric, refers the number of unique individuals receiving a license to produce hemp. This definition can vary some by states. For example, the state of Virginia distinguishes registrations for their hemp program into three separate groups, industrial hemp grower, processor, or dealer each with distinct fee structures and compliance requirements (Virginia Department of Agriculture and Consumer Services, 2020)

Stakeholder relevance
By knowing the number of registrants and how the metric changes across growing seasons, a state department can better plan allocation of resources needed to help growers, processors and vendors remain in compliance with hemp regulations. For example, if the number of registrants doubles in a year, a state department may consider hiring more staff to sample and test THC thresholds, execute inspection procedures, determine seed availability, or disburse additional funds for research and development if needed (*Agriculture Improvement Act of 2018*, 2018). For a grower or vendor, it may be useful to know whether there is ample community support or dense commercial competition in their area by querying a database of registrant locations.

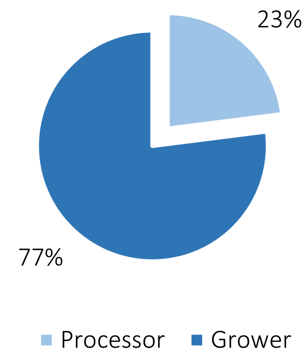


Figure A7. Number of Vermont hemp registrants by type in 2019 (n=1278)

Sustainability, community capitals and interdependence of metrics
The number of registrants informs us about social dynamics around hemp (are farmers willing to grow hemp, are new farmers coming to hemp), financial dynamics (is the crop perceived as profitable) and built capital (are growers connecting to processing facilities, should they exist).

Merits and limitations
The number of registrants shows the magnitude of interest in producing the crop. Additionally, each registrant pays a fee to grow and is a source of revenue generation for states. On the other hand, many small farm growers will complete an application for a hemp license but do not actively begin hemp production unless a profitable opportunity presents itself thereby inflating the belief of growth or interest in the crop.

Data levels and availability
From the VT Hemp Registry, there is data at the level of the primary individual (or operator) registered by age demographic for 2019 but collected only as aggregate data for 2020 listed by intended end-use (VAAFM, 2020). Although there is registrant town data for each grower and processor separately, we do not know whether a particular registrant serves both functions on one farm or whether they host another hemp-related activity like agrotourism or direct vendor. The data file holds many blank entries, and it is not clear whether the value for a particular registrant is zero or they declined to respond.

Recommendation
Obtain consistent data and subtypes across years for registrants by using person-person (virtual or live survey) or an entry system that does not allow for blank entries (NA or 0 is more informative than blanks) or multiple-choice ranges.

8. Farm owner income
Net farmer income is determined by sales of the crop in excess of the expenses of producing that crop and sustaining connected parts of the farm. Assets may also include held inventory, as well as subsidies or insurance payouts. Economic gains resulting from the production of goods and services, including receipts from the sale of commodities, other cash payments, increases in inventories, and accounts receivable are all considered as Financial capital.

Stakeholder relevance
Increasing total farm income from hemp would be beneficial is both beneficial from a financial sustainability standpoint and diversification within the agricultural sector.

Sustainability, community capitals and interdependence of metrics
Within the set of Community Capitals, farm owner income exists within the Financial Capital group, and interacts with other Community Capitals (Flora & Flora, 2013). A profitable farm has positive impact on Social Capital by permitting sustained employment for farm workers, and supporting farm ownership and debt repayment, and Human Capital through supplying jobs for workers and family members. Farmer income may also benefit from and reflect the ***value of the Vermont Brand***, which may command higher prices than related product from out-of-state producers. Consequently, income may interact with Cultural Capital.

Merits and limitations
We cannot, at present, identify what portion of income is derived from hemp sales versus other farm activities from the available data and would require additional language in the Hemp Famer Survey to address this question. It is also unclear how large and stable the market for hemp will be in these early years of production. Long-term this information will be available through USDA-ERS.

Data levels and availability
Producer surveys, from industry journals or federal analysts, may reveal hemp-specific income estimates but these are not yet publicly accessible or require a costly subscription at present. The future AMS/ARMS survey will address this distinction between hemp-specific income and other farm activities but currently this data in not being collected at the state or federal level.

Recommendation
A producer survey is needed to collect hemp-specific income estimates.

9. Number of employees and farm employee wages
This metric describes the average of hourly, daily, weekly, or annual salaries made by a hemp farm owner to a farm employee and is expressed in $ amounts.

Stakeholder relevance
Essential oil is labor intensive and could require wages above other crops to secure the labor resources needed compared to other on-farm or processing activities (Mark and Snell, 2019). A grower may also wish to attract and retain skilled laborers for harvesting, trimming, and drying hemp by offering better wages than neighboring farms or from other states and ensure that wages meet minimum wage or local standards. By understanding the amount of labor required for a harvest, a grower may choose to plant less acreage at the beginning of the growing season in so that labor costs do not exceed a farm's budget.

Sustainability, community capitals and interdependence of metrics
The average farm employee wage informs us about the financial capitals, human as well as social dynamics around hemp. If workers are well compensated, they are likely to contribute to the local economy and choose to work for the same grower year after year, building community stability, loyalty to the grower and ***trust*** (a metric under social capital).

Merits and limitations
Labor costs are one of the largest costs to produce hemp essential oil products (Shepherd and Mark, 2020). This metric can be broken down into many distinct categories: hired labor, management, and unpaid labor. Labor costs for grain and fiber hemp production are minimal (Shepherd and Mark, 2020). A limitation of farm employee wages as a metric is that can be difficult to know what category of labor is being reported.

Data levels and availability
Currently, third party survey data is available for most states but locally, we would need a producer's survey that will likely be included in the AMS survey and inform the criteria for our own survey and analysis.

Recommendation
Develop a survey of farmers to collect information on wages and how they are paid, whether and which benefits are offered, and whether employment if full time, part time, or seasonal.

10. Farm diversification
Farm diversification is a multi-use indicator. Commodity agriculture is not sustainable overall and may be particularly risky in a state like Vermont where the small size means that many large-scale processors may not find it cost effective to source commodities from the region. Diversification can be measured by the number of crops grown, or by more complex indices that balance the relative number of different crops grown (a modified Simpson's or Shannon index, for example).

Stakeholder relevance
This metric can help to measure resiliency to shocks in an economy, crop failure, and entrepreneurial activity. There is a need to understand the issues driving decisions at the farmer (micro/niche) level, specifically, at the scale of small and medium size producers, to understand the systemic effect of diversifying practices that include novel specialty crops. Understanding diversification through an informed decision-making process is necessary for bridging farm gate to end use relationships. Issues of multi-faceted new responsibilities/knowledge, forms of production and scale (processing, manufacturing, marketing, direct sales) are critical for successful implementation.

Sustainability, community capitals and interdependence of metrics
It is critical to recognize the context that frames farm-level decisions by finding factors that drive action toward diversification of practices — or not. These contextual frames include human, cultural, economic, environmental, social, and political factors that serve as motivators or deterrents. Observing the food system through a multi-level perspective allows researchers to understand the complexity of interactions that drive decisions – at the niche level to identify what are developing markets, needs for products, foods etc. that support rural communities and build economic opportunity through development and adoption of novel specialty crop production.

Merits and limitations
Although buyers are often committed (often mission driven) to supporting small and medium sized farms there are many barriers to doing so, including inability to accept raw, unpackaged commodities coming directly from the farm gate and to work with many small-scale farmers or source from a distributor to reach adequate supply. Product aggregation and processing is extremely limited or non-existent for many specialty crops produced on small and medium sized farms. For example, there were 23 processors available to hemp producers in 2018 (Mark et. al., 2020).

Data levels and availability
For small and medium farms, diversification is likely a key economic and social sustainability metric. More information on economic and social benefits (and drawbacks) of diversification are needed. There is currently no data on the farm-level diversification of hemp growers in the state.

Recommendation
A grower survey is needed to address questions about farm diversification activities.

11. Processing facilities

Processing is a post-production handling stage that serves as a critical link in the supply chain, converting hemp grains and biomass to usable material which can be introduced into various bioproduct manufacturing applications. Processing employs mechanical and/or chemical operations to convert raw material into usable material streams, potentially making use of the whole plant. Understanding the capabilities and scales of processing infrastructure will enable viable market development for hemp material streams. This number of processing facilities, density within a geographical area and their distance from growing areas are metrics to be gathered to inform sustainability of the hemp agricultural system.

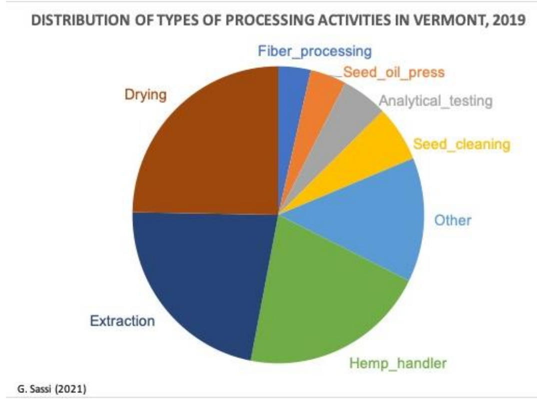


Figure A11. Types of processing activities in Vermont in 2019 (VAAFM, 2020).

Stakeholder relevance

Development of processing infrastructure and knowledge of processing capabilities can affect decisions at the individual producer level, identify needs and opportunities for infrastructure investment, encourage or discourage formation of cooperative efforts/organizations, and determine amount of prepared source biomass for manufacturing applications. At the farm-level, producers may decide to integrate vertically. Processing allows for the development of niche markets and catalyzes the potential growth toward adoption at the regime and ultimately integration at the landscape levels toward consumer acceptance. At the policy level, processing facilities supply services that are subject to licenses and permits to operate that is dependent on state and local regulations (Parker et al., 2019).

Sustainability, community capitals and interdependence of metrics

Financial investment could spur market development leading to increased farm revenue. The current built environment could support the necessary infrastructure, leading to revitalization of former large industrial sites that previously supported agriculture or other manufacturing. An increase in demand for processing can lead to social formation of shared services through cooperative ventures. Enactment of policy to support new innovative entrepreneurial ventures could spur rural manufacturing from locally sourced bioproduct. New processing and manufacturing would spur a need for human capitol, creating new opportunities for skilled labor and could serve to reduce out-migration from rural communities.

Merits and limitations

Processing is a critical link in the value stream, connecting producers to markets. Logistics of proximity to processing will have a direct impact on biomass revenue for the producer. Processing facilities are limited by the available raw product and differing quantities and qualities of supplied material. Some processing may have seasonal demands, while other processing could run year-round with proper drying and storage facilities. Storage and transport of hemp raw or processed products between facilities may be affected by scaling challenges of product traceability and quality control, security (as shown with reports of thefts and break-ins in Vermont in 2020), compliance with production regulations or food safety policies. Therefore, measuring the density and number of facilities within a geographical area may be useful as an indicator of sustainability but it does not fully capture the required quality controls, volume capacity, manufacturing standards or compliance issues for smooth operations.

Data levels and availability

Current data is limited to individual state registries as individual states develop policy that govern processing facility permitting. In Vermont, 2019, 293 individuals voluntarily identified as hemp processors with a fraction of respondents, ~18%, also registered as hemp growers although it is not clear whether the same individuals simultaneously managed both activities (pointing towards vertical integration) (Figure A11). The registry also includes data about whether each processor obtained raw materials from local or out of state growers yet the proximity (in distance) between growers and processors was not reported. In terms of transportation, environmental impact and feasibility of establishing a processing business, knowing the distance or density of area growers: processors: vendors would provide an indication of community-built capital and local saturation or sustainability of small and medium hemp endeavors. Nationally, product extractors and manufacturers represented a little over 7% of the total established number of hemp businesses (1600-2000 out of 27950 primary, secondary, tertiary sectors) in 2017 (Parker et al., 2019). This sector remains as one of the primary barriers, along with quality and consistency of products, of commercialization of hemp at the national scale (Schluttenhofer and Yuan, 2017).

Recommendation

Coordinating state registries and establishing reporting mechanisms for facilities would reflect the market strengths and help to identify material dependent manufacturing industries. The development of regional processing facilities could have a positive impact on rural employment opportunities and spur regional manufacturing enterprises. Clear and explicit protocols for traceability, quality control, ensuring food safety and removing barriers between the growers: processors: vendors is paramount as the local industry plays catch up with the popular demand for products.

Environmental Metrics

12. Nutrient mass balance

A farm-gate nutrient mass balance is defined as the difference between nutrients imported in feed, fertilizer, animals, bedding, and manure, and the amounts exported off farm in milk, meat, crops, manure, or other products (Cela et al., 2015).

Stakeholder relevance

Specifically, nutrient mass balance is helpful to hemp stakeholders (from farmers to environmental managers) as a measure of the amount of inputs (nitrogen and phosphorus fertilizer) to generate a particular output. Considering the phosphorus pollution issues in the Champlain basin and in many other regional watersheds, this is an important metric as it influences whether increasing hemp production may reduce or worsen regional water quality issues tied to phosphorus.

Sustainability, community capitals and interdependence of metrics

Nutrient management intersects with several capitals, although it is primarily a natural capital. High nutrient needs for a crop may contribute to runoff of nutrients into waterbodies, and the host of environmental problems this can cause. Nutrient inputs are also expensive, and greatly influence profitability of crops. As runoff and water pollution have consequences for other sectors of the Vermont economy, they also become social capital issues.

Merits and limitations

The goCrop™ tool developed by University of Vermont Extension (University of Vermont, 2018) now has a feature to calculate nutrient mass balances on farms. The Cornell Mass Nutrient Balance Tool is available for free download (Cornell University, 2021). Advantages of using farm-gate nutrient mass balance include: (1) evidence that nutrient mass balance can be a useful proxy for losses of nutrients to the environment (runoff or leaching to water, gaseous N losses to atmosphere) (Cassman et al., 2002; Grassini et al., 2012; Groenigen et al., 2010; McLellan et al. 2018; Van Groenigen et al., 2010), (2) easier data collection in comparison to direct measurements of environmental losses, (3) provides a consistent framework for application across farms, and (4) results in nutrient use efficiency metrics that are useful to farmers from an economic perspective. Required soil testing and nutrient management planning can be complemented using farm-gate nutrient mass balance and Farm-PREP modeling. Farm-PREP is an integrated web-based application developed by Stone Environmental (Stone Environmental, 2019) that models phosphorus runoff from fields. This software will be used within the State of Vermont's forthcoming Vermont Pay-For-Performance Program (VPFP), which is a pay for modeled performance approach that pays farmers for the pounds of phosphorus loading to aquatic ecosystems reduced by implementing conservation practices (VAAFM, 2021). Farm-PREP uses the USDA NRCS farm-scale water quality model, the Agricultural Policy Environmental eXtender model (APEX), to evaluate thousands of farm management scenarios (Gassman et al. 2009). However, it is currently not possible to model hemp in this platform. Doing so will require further data collection.

Data levels and availability

Although the goCrop™ platform will help handle nutrient mass balance data, we need additional data specific to hemp production across a variety of management styles, soil types, and production systems.

Recommendations

We recommend further streamlining of the data collection process for whole-farm nutrient mass balance calculations on hemp farms and stakeholder engagement to aid interpretation of mass balance results. We recommend generating the data necessary to include hemp in the FarmPREP (APEX) model being used in the Vermont Pay-for-Phosphorus Program, including hemp crop growth parameters, hemp agronomic practices, crop rotations, operation schedules, and other key information to model water quality goals across multiple fields, aggregated to the farm scale.

13. Water usage

The amount of water applied to the crop. Either total water applied, total water needed, or average irrigation needs. Standard metrics for water usage are in volumes or widely used irrigation metrics such as acre/feet of water.

Stakeholder relevance

Water usage can tell new growers how much water infrastructure they will need. This metric may give a sound rationale for not growing hemp in areas where water is in short supply. Expected water usage indicates whether the crop will require farmers to pay for irrigation or buy water.

Sustainability, community capitals and interdependence of metrics

Water is an important form of natural capital. Hemp water usage however also intersects with several other capitals. Because planning for water usage in the face of climate change requires facing likely increased variation in precipitation, it involves built capital (irrigation infrastructure and tiling fields) and financial capitals (profitability of farming operations).

Merits and limitations

Survey data are needed to evaluate water usage. If hemp fields are small, or part of diversified farms that already have irrigation infrastructure, it may go unassessed.

Data levels and availability

Little information has been published about the water requirements of hemp. Most sources describe hemp as having relatively high-water requirements, especially during the first few weeks after seedlings are transplanted and root system is developing, but little to no published sources are cited. The limited research trials done to determine irrigation requirements use corn evapotranspiration rates to determine the water needs of hemp, since rates for hemp have not been determined. Research is also limited to specific locations (county/state level) and not much regional data are provided. Other research highlights the effect of drought on hemp yield and quality, or varietal differences in drought tolerance.

Recommendation

Survey data on hemp water usage are needed. We recommend that the AMS production survey include information on hemp water use in Vermont. Creation of a model to assess water use in hemp production, such as The Cool Farm Tool, may be a useful resource for growers (Hillier et al. 2011).

14. Carbon cycling

Soil carbon sequestration on agricultural lands has become part of the global carbon agenda for climate-change mitigation and adaptation. Net soil carbon sequestration is a function of carbon inputs to the soil (e.g., crop residues, manure, mulch) and carbon losses to the atmosphere (e.g., soil respiration) and water (e.g., soil erosion) (Amelung et al. 2020). Furthermore, soil carbon dynamics depend on soil fertility and conservation measures (Sykes et al. 2019). Soil organic carbon positively affects soil structure, water retention, and nutrient supply, and therefore is crucial to agricultural productivity (Oldfield et al. 2019).

Stakeholder relevance

Soil carbon is emerging as a central aspect of soil health and is a key part of climate change mitigation and adaptation. For farmers, it influences soil water holding properties and the availability of a range of other essential nutrients (micronutrients such as sulfur, but also macronutrients like nitrogen, phosphorus, etc.). For a broader set of stakeholders, soil carbon levels in agricultural soils affect atmospheric carbon levels; agricultural soils may hold potential to sequester atmospheric carbon on a global scale, while reducing further loss of soil carbon to the atmosphere is widely agreed to be of critical importance.

Sustainability, community capitals and interdependence of metrics

Soil carbon is a natural capital, but as with many other environmental metrics it has financial impact. Soils with great soil carbon hold more water in drought, drain more readily in heavy inundation, hold more nutrients and require less fertilization, and have reduced susceptibility to some diseases, making them financially more valuable.

Merits and limitations

Measurement and verification of soil carbon sequestration is challenging because (1) changes in bulk soil carbon occur slowly (Smith 2004), (2) it is not currently feasible to verify C sequestration rates that increase total soil organic carbon stocks by <1% on an annual basis using direct soil measurements (Paustian et al. 2016, Smith et al. 2020), and (3) alternative methods that infer soil organic C changes from flux measurements to construct a full carbon budget can be comparatively uncertain (Smith et al. 2020). Measurement of individual fluxes (e.g., C input to soil from hemp crop residues and/or soil amendments) is a tractable approach that can potentially help show relative soil C sequestration potential, though any potential based on a single flux (e.g., C inputs to soil) may not accurately predict net soil C sequestration once other fluxes are considered. New spectral methods may eventually supply a way to check soil organic C at several hemp farms across Vermont, but further advancements are needed to resolve measurement uncertainties and reduce costs (Smith et al. 2020). Active soil carbon (i.e., permanganate oxidizable C or POXC), which quantifies labile soil C rapidly and inexpensively (Culman et al. 2012), may provide another method for monitoring soil carbon cycling. Models can be used to estimate C cycling in cropland systems as well. Numerous models exist, such as the Cool Farm Tool, which is focused on decision-support, and requires inputs that farmers typically have good knowledge of (Hillier et al. 2011).

Data levels and availability

von Wettberg and Voigt have examined hemp production with black plastic ground cover versus hay and legume cover crops as groundcovers. Although active carbon data is still be generated due to COVID-19 backlogs, this experimental work may help parameterize models of soil and plant carbon dynamics in Vermont. Roy has existing bulk and active carbon measurement protocols in use in his lab (RSENR).

Recommendation

In Vermont, we need carbon data for soils analysis and modeling in hemp production across a range of soil types, and across any variation in production systems. This recommendation would occur in parallel to work on nutrient management and mass balance (above).

15. Soil erosion
Soil erosion is a major global challenge, with perhaps 50% of the world's topsoil having been lost due to agricultural activities over the past 150 years (FAO, 2019). Erosion can be measured in multiple ways, from field plots to watersheds (e.g., Lal 1994).

Stakeholder relevance
Apart from high-input hydroponic production, crops ultimately require soils, which hold water and nutrients, for production. Soil loss from erosion not only degrades the productive value of agricultural land but causes downstream environmental problems such as silt accumulation and water pollution.

Sustainability, community capitals and interdependence of metrics
As with our other environmental metrics, this is a natural capital that has effects on other capitals (financial, social, built, etc.) through its impacts on farm productivity and the broader community. Because soil is very slow to build from rock weathering and deposition, and because soil carbon is a major global reservoir of carbon that holds ten times the carbon of the atmosphere, retaining soil is critically important. Because erosion has downstream effects, it does impact social capital.

Merits and limitations
Erosion is perhaps not the best metric, as current hemp farming management approaches tend to not be major drivers of erosion. Most Vermont farmers are tilling soil, and then using black plastic to protect hemp that has either been directly seeded or transplanted. Although the tillage can expose soil and lead to some early season erosion, the black plastic likely protects the soil through the rest of the season.

Recommendations
We recommend that erosion reports be included in regular surveys of farmers, to determine if hemp practices are causing erosion to increase.

16. Soil health

Soil health is a nebulous metric, as there is no single quantitative measure of it. We consider it however, as multiple aspects of soils are important metrics and because it is a point of connection to the Soil Health White paper group. Soil health gets defined in different ways in different contexts and researchers. It may be defined by the capacity of a soil to supply the nutritional needs of a crop, or the capacity to suppress crop diseases. In a "One-Health" framework it may be defined in terms of human or livestock diseases that it harbors. For some, it is a nearly mythical property that is increased by regenerative farmers. Several quantitative aspects of soil health, such as nutrient management and soil carbon, we have described separately, as these are good quantitative metrics.

Stakeholder relevance

Within our stakeholder group, there was enthusiasm for soil health. Among one of the farmers, there is the mythic reverence for soil health as an aim of regenerative farming. Among others, measurable metrics were more tractable.

Sustainability, community capitals and interdependence of metrics

Aspects of soil health will likely prove to be important metrics, affecting both a range of natural capitals (carbon, nitrogen, phosphorus and other mineral cycles, water, etc.) and their interaction with other capitals such as financial ones.

Merits and limitations

Because of its nebulous nature, soil health as a single metric has low merit. But separate aspects of soil health, such as soil carbon content, are important metrics for hemp production.

Recommendations

As hemp production expands and the industry matures, collecting on-going soil data from farms will be important to helping guide farmers to maintain aspects of soil health, from nutrient levels to soil carbon.

17. Agronomic practices

The agronomic practices involved in hemp cultivation can have an impact on crop productivity, farm economics, and the surrounding environment. At this point, how a farmer decides to approach hemp production will likely be influenced by early adopters and early research. Since hemp is new to many farmers, technical service providers, and researchers, there is no standard production scheme. Regardless, stakeholders are experimenting to develop that suite of best practices to successfully grow a crop. Practices that ensure a viable crop generally are prioritized first. Since modern day hemp production is new to farmers researchers and markets really could help set the "standard practice" so it is focused on maximizing crop and environmental productivity. A full cycle analysis is needed to estimate the impacts of fertilizers, any pesticides, groundcovers, machinery, and other inputs that may be used to rear a hemp crop in Vermont. Other hemp life cycle analysis in the literature have been conducted on hemp fiber which shows favorable low impact results for hemp compared to other crop such as corn and wheat. However, this assumes the use of good agricultural practices in a hemp fiber production system (van der Werf, 2004). With most farmers currently growing hemp as more of a horticultural crop an analysis of practices should be conducted to assess environmental impacts under various agronomic practice scenarios.

Stakeholder relevance

In the context of Vermont, information on how hemp agronomic practices might impact phosphorus pollution is still needed. In other crops, such as corn, significant research, education, and financial support has gone into encouraging farmers to adopt conservation practices to minimize the environmental impact of crops. Research to develop best practices with both farmer and environmental goals in mind will help most hemp stakeholders meet individual objectives. Growers will be able to produce a high yield and quality crop at lowest production and environmental cost, potentially improving farm viability and enhancing market opportunities. End users will have access to a high-quality crop that can be marketed as environmentally safe.

Sustainability, community capitals and interdependence of metrics

Agronomic practices are a place where natural capital (climate and the fertility of soils) meets cultural capital (practices used) and built capital (farm infrastructure).

Merits and limitations

The chief limitation is a lack of research on hemp agronomy. Recent research by Darby's team in Vermont has supplied much of the knowledge available to growers in the northeast. However, more work is still needed across soil types, production approaches and hemp end-uses (fiber, grain, flower). Development of viable practices is key, but side-by-side research that evaluates the environmental impact these practices impart will help further prioritize best practices for growing hemp.

Data levels and availability

Much of the data for agronomic characteristics of hemp is in the following citations from Darby's research group (Darby et al., 2017a; Darby et al., 2017b; Darby et al., 2017c). Additional data being generated outside of the state but in other temperate climates will also be valuable to Vermont growers.

Recommendations

There is a need for more agronomic research, building on the foundation laid by Professor Darby, that focuses on development of agronomic practices that optimize crop productivity *and* environment needs to be prioritized. Optimizing resources and expediting research is critical as the industry grows quickly with or without this information. We recommend that the AMS production survey incorporate data on the production practices being implemented by hemp farmers, including crop rotations, cover crops, reduced tillage, nutrient management, soil testing, water buffers, crop diversification and scouting.

18. Pesticide use

The pesticide metric evaluates expenses and types of chemical inputs used on hemp. The EPA has recently registered several dozen biopesticides (chemicals derived from natural biological sources such as oils, or the organisms themselves) or use on hemp (EPA, 2020). Vermont has approved a small list of pesticides for use on hemp. Much data indicates that hemp has few pest issues and pesticide use overall should be minimal. However, research on hemp grown for essential oil or flower bud production has a large cadre of disease, insect, and weed issues. In addition, effective controls are lacking for important pathogens, such as downy mildew or powdery mildew. As pesticide registration for use on hemp continues, the overall pounds of active ingredient applied to the crop will continue to increase.

Stakeholder relevance

Grower stakeholders must have crop protection tools that are effective enough to outweigh costs. Currently, there are few pesticides available for hemp production and the efficacy of many are unknown. Regardless, growers must assess the potential risk of pesticide residues being detected on the hemp crop being sold. Hemp flower buds are often sold into the smokable or edible markets and material free of contaminants is required to meet this high value market. Consumer stakeholders may make buying decisions based on perceived quality of product.

Sustainability, community capitals and interdependence of metrics

Pesticide use may impact elements of Natural Capital, such as water, which must be protected from contamination, or soils. Illegal use of non-registered pesticides poses a special risk. Pesticides are costly and their use affects Financial Capital. Some growers may choose organic production methods and leverage higher prices by limiting pesticide use.

Merits and limitations

Pesticide use data would help us understand the scope of these inputs and supply field data for effectiveness. Analytical chemistry studies can reveal how much pesticide product makes it into end products. This is a good indicator of the amount of pesticide needed. In hemp, no pesticides are currently listed. Research needs to be conducted to develop integrated pest management programs for hemp farmers to minimize pesticide usage and optimize yield and quality. Breeding programs focused on disease resistance will also greatly reduce the need fungicides and other disease control products. Some farmers will seek USDA Organic Certification. Although this does not eliminate the use of pesticides, it does clearly limit the types of pesticides to those that generally fall into the biologicals category.

Data levels and availability

The Vermont Agency of Agriculture is charged with governing and monitoring pesticide use in in the state. The Crop Protection Division, approves the use of pesticides in Vermont, certify pesticide applicators, and tracks pesticide usage by product sold. Hence there is no crop-specific data available. The Agency of Agriculture also regulates industrial hemp production and sets the registration requirements and standards. Currently the state requires that hemp be tested for pesticide residues, which went into effect during the 2020 growing season. As such, there is little data available to understand whether pesticide residues are keeping crops from making it to the market. It is not clear if aggregate data on hemp quality will be made available to the public.

Recommendation

Further studies on hemp diseases and control can spur the development of integrated pest management approaches to reduce disease and cost. In addition, plant breeding programs are necessary for industry success. Pesticide usage could be a self-reported metric through farmer surveys. Consumer survey data could reveal attitudes toward pesticide-treated products, as well as farmers' use of off-label products. An understanding of market requirements and developing industry standards for quality can help set Vermont's priorities to the highest level in order to garner a high value share.

19. Open space
Open space is the amount of land without buildings or impervious surfaces. Preserving open farmland has a range of ecosystem service benefits that can be easily captured from open space alone. It can also serve as a measure of the rural-urban interface, indicating how much land remains without artificial, impervious surfaces. Open space can be measured as area, or as a percentage of a larger area (open space per town).

Stakeholder relevance
This metric is attractive in being easy to gather from overhead image data from public sources (e.g. Landsat). With easy tools such as google earth, it can be calculated by those without advanced geospatial training. With historical aerial and satellite data, one can easily collect open space data over time as well. It can also be processed at a variety of scales, from properties to municipalities, counties, or statewide.

Sustainability, community capitals and interdependence of metrics
Open space is shared with the agritourism group as a metric that, due to its ease of collection, is valuable, even if it has shortcomings in its ability to accurately capture other environmental values.

Merits and limitations
The value of using open space as a proxy for the breadth of ecosystem services is that it can capture the potential of land to hold soil carbon and the crop itself to sequester carbon in its stem and roots, the potential value of the agricultural habitat for pollinators (even if hemp produced for CBD is not pollinated and attracts few if any pollinators, a hemp field may have other plants around it that do), water filtration that happens on unpaved land, nutrient cycling, and the value of open farmland for agritourism.
The value of open space is not all equal. Hemp produced for CBD under black plastic may stimulate soil respiration, lowering soil organic matter and so water holding capacity, filtration, and the potential of the soil to hold nutrients for subsequent crops. As a result, the value to soils may be much lower than other production systems. Although it may be possible to identify hemp from overhead images in the summer because of its unique spectral signature, details of hemp agronomy (black plastic usage, water or fertilizer applications, pesticide usage) that matter for its sustainability cannot be easily gleaned from overhead imagery.

Data levels and availability
Overhead imagery data is already easily available, in many forms. Remote sensed data can be used along with hemp production registrations to provide insight into whether hemp helps maintain the open nature of much of the Vermont landscape, and how that varies across the state. Changes can be detected by comparing longitudinal open space data. It can also be used alongside state registry data to verify reported acreage.

Recommendation
We recommend examining open space at the rural-urban/suburban interface, to determine whether hemp farms in Chittenden country or other more urban areas are potentially contributing to the preservation of open space in peri-urban areas where development has most threatened open space and the value it provides. Hemp monoculture will eventually lead to yield decline, as it does for all crops. Overhead imagery over time can provide some insight into possible rotations.

20. Rural-urban interface
As a unique specialty crop that is attractive to many new farmers and has potential for strong demand in more urban areas in Vermont, hemp as crop could help protect urban/suburban boundaries, keeping farmland open. We define this as the distance (kilometers or imperial units) of a farm to the nearest urban area, making it a tractable measure.

Stakeholder relevance
Protecting farmland and associated open space is important not only for protecting local food and agricultural production, but for the environmental values of open space. The measure of farm distance to urban area affects food miles (carbon intensiveness) and potential for local marketing and impacts urban-rural social relations. This affects stakeholders through the cost of the crop and returns to the grower and can provide producers and consumers with a more intimate connection.

Sustainability, community capitals and interdependence of metrics
Like *open space*, this metric capture some of the natural capital farmland can provide. Unlike *open space*, it may also speak to the interrelationship of rural societies with urban ones. Having farms closer to cities reduces the transportation costs of foods and can both physically and culturally bring urban consumers closer to their food and other agricultural products. Although hemp is not a food crop, if hemp farming near urban areas preserves farmland, or allows more urban dwellers to "know" a farmer, it still supplies many of the same benefits.

Merits and limitations
One limitation is that farm distance to city is not the only measure of the rural-urban interface. But as something that can be calculated from a farm location, it can be measured from registry or overhead image data.

Data levels and availability
The Vermont Agency of Agriculture currently tracks the farm locations and business zip codes of registered hemp operations (VAAFM, 2020). These data enable further analysis of the rural-urban interface described above.

Recommendations
We think this metric deserves further consideration to determine how well it connects to measures of social sustainability. With registry data, we can assess whether hemp production is closer to more urbanized areas near Burlington or elsewhere in Vermont.

Socio-Political Metrics

21. Consumer awareness and preference

Consumer awareness refers to consumer familiarity with hemp as a crop and its various products. We also consider consumer perceptions surrounding hemp production and the traits of hemp products, such as sustainability and associations with marijuana. The more consumers are aware of hemp and its products, the more likely it is they can see hemp as part of their purchasing patterns (Kolodinsky, Lacasse & Gallagher, 2020). Consumer preference for and use of hemp products indicates acceptance and accessibility in the marketplace (Kolodinsky & Lacasse, 2020).

Stakeholder relevance

Consumer awareness and preference will direct the industry on the best types of hemp to farm and which affiliated industries may lead to enhanced community development. Consumer preference can identify which aspects of hemp products appeal to consumers and direct market and/or public education efforts.

Sustainability, community capitals and interdependence of metrics

This metric interacts with economic dimensions by dictating which hemp products are more likely to succeed in the market. The application of consumer awareness and preference to direct industry priorities may also bolster the ability of communities to generate human capital and community development.

Merits and limitations

Consumer awareness and preference can measure the market implications of hemp's various products. However, current data limitations include a focus on hemp CBD products and do not fully represent the broad array of products hemp can produce.

Data levels and availability

Vermont data on awareness and use of hemp products are available through the Center for Rural Studies.

Recommendation

Data on purchasing patterns and demand for *all* categories of hemp products should be collected in order to fully understand consumer awareness and perception.

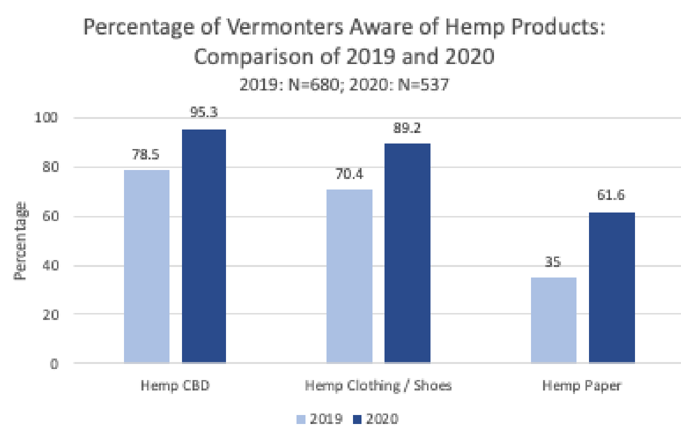


Figure A21. Percentage of surveyed Vermonters aware of hemp products. A comparison of 2019 and 2020 (2019: n=680; 2020: n=537) (Kolodinsky & Lacasse, 2020).

22. Politicization of hemp vs CBD
The politicization of hemp vs CBD will be measured using voting records of state legislators and senators in support of hemp. The value of assessing politicization is to better understand the local community acceptance of hemp vs CBD. It can help hemp stakeholder to better understand the support they have within the area they operate. Data is available at the county level.

Stakeholder relevance
Politicization of hemp can have an impact on the policies and regulations at the local, state and federal level, which has direct effect on hemp operations.

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-Political Impacts, such as *trust.*

Merits and limitations
Hemp can hold stigma within communities due to legal concerns and lack of awareness. Knowledge about a community's political views on hemp can help stakeholders understand future challenges faced (Pal & Lucia, 2019). Further, the political leanings of a community can have impact on state-wide policy towards hemp research and development (Mark et al., 2020). This metric also aligns with the ***trust*** metric.

Data levels and availability
County and state level data are available via Vermont.gov.

Recommendation
Data on county and state voting regarding hemp should be collected, as well as the measure of the percent of population registered by party in a county. Identification of the political party of the state rep and senator will be necessary for analysis.

23. Demographic characteristics of the industrial hemp industry
This metric looks at the demographic characteristics of individuals within the industrial hemp industry, such as age, gender, race, etc.

Stakeholder relevance
Greater information on who is currently involved in the hemp industry can shed light on the challenges for underrepresented groups and could have policy and regulatory implications.

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-Political impacts, such as *trust* and *political capital.*

Merits and limitations
Demographic information can show who is and is not part of the industry. Further research can explore the reasons for inclusion or exclusion. Data for gender and race is particularly important as substantial evidence has been found that they are the basis for discrimination (Horst & Marion, 2019). Data for gender and race is often not collected and attributed to low figures. However, qualitative data collection can be collected absent sufficient quantitative data. Other merits include understanding of how financing, production and processing varies for and between diverse groups. This has implications for future policy and regulation that might aid underrepresented groups.

Data levels and availability
It would be ideal to have data at the farm level, which would allow further extrapolation. The NASS 2017 Agricultural census collects demographic information but has yet to include hemp-specific farmers. In Vermont, there is limited demographic information in terms of demographics.

Recommendation
Demographic data collection in grower and producer surveys should be prioritized. Including qualitative data collection to supply broader understanding of underrepresented groups is critical.

24. In/out of state ownership
This metric measures the number of hemp operations owned by individuals living either within the state of Vermont or outside the state.

Stakeholder relevance
The ownership of the land has a direct impact on the decisions of farming production (USDA ERS, 2020), which has a downwind effect on the local community. In-state ownership may have a priority to buy farm inputs from in-state service providers, which has a direct effect on the local economy. Out-of-state owners may have a lower priority to the local community and thus may have less interest in supporting the community through local purchasing and hiring (Wasti et al., 2016). Production inputs could potentially impact community wellbeing (e.g. odors, *see Additions/detractions to community)*.

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-Political impacts such as *social capital*, *political capital*, and *human capital.* It also interacts with Economic impacts.

Merits and limitations
This metric can help stakeholders, service providers, policy makers and academics to better understand how ownership can impact how a farm operates, including sources of inputs, labor and other operational decisions made. However, there is an absence of data for this metric, which prevent generalizability.
Data levels and availability
There is currently no data available for in/out of state ownership in Vermont.

Recommendation
We recommend that a yearly survey to farmers include a question regarding residency.

25. Number of farm families
This metric refers to the number of farms that are owned and operated by families.

Stakeholder relevance
The number of family farm has indications on the size/scale of farms, generational investment in land and community.

Sustainability, community capitals and interdependence of metrics
This metric interacts with all aspects of the Socio-political, Economic and Environmental impact metrics.

Merits and limitations
Family farms make up a majority of agricultural operations in VT (approximately 80%) (USDA & NASS 2019) and are primarily small and medium-sized in scale (Hoppe, 2014). Family farm operations are critical participants in their communities, particularly rural ones (Howorth et al., 2010), meaning that they have a vested interested in the economic vitality of their local community because the community is also part of their consumer base. Family firms also have an interest in maintaining its own financial future even at the risk of present-day losses (Glover & Reay, 2015), meaning that they are more likely to reinvest in the firm to increase the likelihood of generational scale. This investment also increases the economic future of the local economy. From an environmental standpoint, family farms have a greater likelihood of land stewardship (Glover & Reay, 2015), which is also connected to the generational firm ownership point.

Data levels and availability
This data is currently available at the state level through NASS agricultural census.

Recommendation
We recommend that any survey of farmers to also collect information on whether the operation is a family farm.

26. School tax base

The education tax rate metric supplies information on how much a community (town/city) is spending per pupil living in the community. This rate is set based on property tax revenue needed to fund education (Ladd 1975).

Stakeholder relevance

The higher the education tax rate, the higher the property taxes, the higher the property value.

Sustainability, community capitals and interdependence of metrics

This metric interacts with other Socio-Political impacts, such as *trust*, *consumer awareness*, *policy and regulations,* and *politicization of hemp*. This metric also interacts with Economic Impacts and Environmental Impacts.

Merits and limitations

Understanding a community's school tax base can supply information on the financial health of a community as well as the types of properties in the area (Ladd, 1975). This has implications on the engagement of a community, which can impact its engagement and support of agricultural operations. This metric can also be aligned with metrics like *consumer awareness* and *policy and regulations*, as higher tax base means wealthier communities that may have greater participation in local politics. This also has implications of the wellbeing of a community.

Data levels and availability

Currently, there is town-level data available through the VT Department of Taxes.

Recommendation

Tax data should be used along with other Socio-political metrics to gain a better understanding of community context.

27. Policy and regulations
This metric refers to the number of policies and regulations related to hemp (e.g. permitting, zoning, testing, etc.).

Stakeholder relevance
The number of regulations make hemp growing more/less accessible to potential growers (Mark et al., 2020). Further, policy and regulation can have an impact on the sustainability of industry for growers (fees, testing, permitting, etc.) and create barriers to entry.

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-Political impacts, such as *trust.* It also interacts with Economic Impacts and Environmental Impacts.

Merits and limitations
Understanding policy and regulations can shed light on the various steps of the hemp production and processing system. From inputs to final consumer usage, policy has impact throughout the value chain. Currently, there is a lack of clarity of policy and regulations regarding hemp, which is a limitation. There is significant variation between state policies and regulations. Therefore, it is important to watch this metric over time.

Data levels and availability
Limited data is available about policy and regulation as state guidelines have not been published due to changes in the 2018 Farm Bill.

Recommendation
Policy and regulation are emerging metrics that need to be watched.

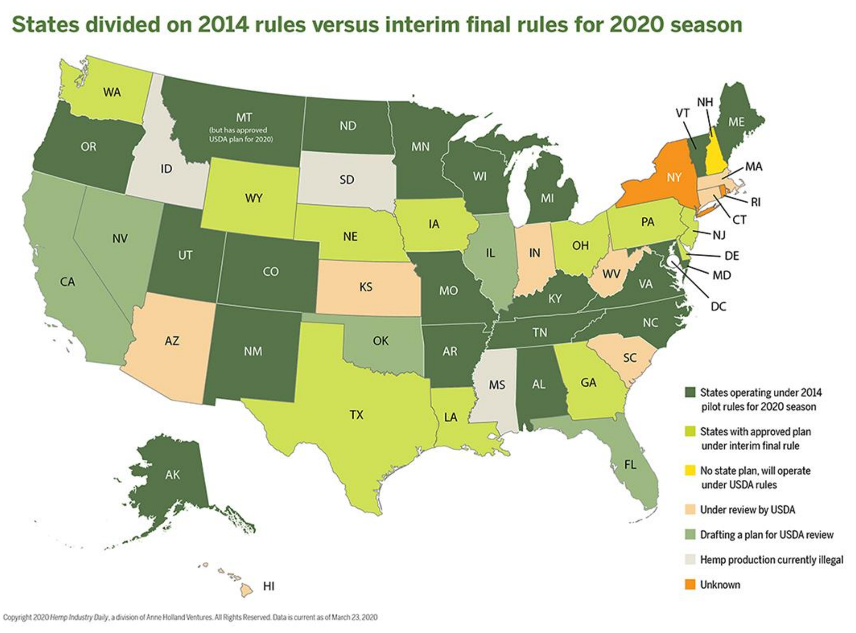


Figure A27. Status of states based on approved hemp plans by USDA. Source from Hemp Industry Daily (Drotleff, 2020).

28. Trust
This metric can be defined as (1) citizen trust of industrial hemp operations, (2) producer trust of neighbors and community and (3) trust in institutions by both citizens and producers.

Stakeholder relevance
With politicized products such as hemp, trust plays a crucial role in consumer perceptions (Dierks, 2007). From the producer side, trust affects the willingness to take part in applications and programs that may help production and processing of crops (Jakku et al., 2019; Rogers, 1995).

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-Political Impacts, such as *politicization of hemp, and policy and regulations*. This metric also interacts with Economic and Environmental Impacts.

Merits and limitations
Understanding this metric can shed light on public policy measures (related to citizen trust), producer wellbeing, and the participation and actions of both citizens and producers.

Data levels and availability
There is currently limited information about citizen and producer trust.

Recommendation
Annual citizen and producer survey questions regarding trust in industrial hemp operations, production processes, and institutions are needed.

29. Value of the Vermont brand
This metric refers to the monetary and cultural value to Vermont as a brand.

Stakeholder relevance
Consumer willingness to pay for the Vermont brand has implications for growers in terms of economic value of the product.

Sustainability, community capitals and interdependence of metrics
This metric has interactions with other Socio-political Impacts, such as *trust*. It also has interactions with Economic and Environmental Impacts.

Merits and limitations
In previous studies, it has been shown that *Vermont* commands positive connotations and Vermont branded products can supply 10-15% increase in the marketplace (Moulton, ND). The Vermont brand is a protected entity and there may be limitations on how the brand name can be used by hemp producers/processers.

Data levels and availability
There is currently no data available about the value of the Vermont brand associated with hemp.

Recommendation
Consumer willingness to pay for hemp with the Vermont brand should be collected via survey.

30. Addition or detraction from community capitals
Co-location of farms near community centers or suburbs can result in externalities with negative consequences. Any set of metrics should include negative aspects as well as positive. Measuring odor explicitly may not capture the impact of the metric. Residents' perceptions may be better indications. For example, in Greeley, CO, where there is a large beef slaughterhouse, residents note that the community is a great place to work and supply anecdotes about "closing windows on days the line is up" (personal communication, Kolodinsky, 2019). Hemp farms may face similar odor externalities.

Stakeholder relevance
Large dairy, poultry, or swine operations have been associated with negative odors, water contamination, pest issues (flies), and more. Every member of the community is a stakeholder, including residents, businesses, and other organizations including non-profit and governmental. It is unlikely that hemp production results in the extent of negative health impacts that a CAFO produces. That said, the odor of hemp is not appreciated by everyone. The Oregon Mail Tribune (Tornay, 2018) reported that the proximity of a hemp production operation near a school results in "noxious odors," and "Many staff, students and families have significant concerns about noxious odor during the harvest season and its impact on the health of the students and the staff."

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-political dimensions, such as *trust.*

Merits and limitations
There is an on-going debate about production agriculture and associated industries and their detraction from positive impacts on economic, environmental and social capitals. Such a metric can provide input into the debate but will not solve the disagreement on who should benefit from agricultural enterprise.

Data levels and availability
There is no evidence that the odor impacts physical health negatively. In data collected by the Center for Rural Studies in 2020, some respondents indicated that they were opposed to hemp production in the state due to its smell.

Recommendation
Citizen distance from the nearest hemp farm may be an important metric for understanding the implications of hemp production presence on community acceptance. That said, a consumer survey including a question about "nuisance" agriculture would provide a human lens.

31. Knowledge base
This metric refers to the level of knowledge base of hemp farmers.

Stakeholder relevance
The knowledge base a hemp farmer can draw from can impact the sustainability of hemp operations.

Sustainability, community capitals and interdependence of metrics
This metric interacts with other Socio-political Impacts, such as *trust*. It also interacts with Economic and Environmental Impacts.

Merits and limitations
Knowing the status of hemp farmers' knowledge base can have implication on the level of support provided by communities/states to operators (e.g. availability of educational opportunities, Extension services, or other farmers).

Data levels and availability
Currently, there is no data available for this metric.

Recommendation
We recommend including questions that capture the extent and sources of knowledge base on statewide hemp farmer survey.

32. Financial loans and networking
This metric refers to the flow and availability of capital for industrial hemp growers.

Stakeholder relevance
This metric has implications for access to land, risk management, and presently, loss due to the COVID-19 pandemic.

Sustainability, community capitals and interdependence of metrics
This metric relates to both community and economic aspects of the community capitals.

Merits and limitations
Data on the flow and availability of capital for hemp growers, as well as the knowledge of these resources by hemp growers, can shed light on who has access to not only the capital but also the various inputs needed to be successful. Specifically, the availability of capital, who is providing the capital (institutions, venture capitalists, other), and how growers and processors are accessing the capital. Further, how are those providing capital managing the risk of investment in industrial hemp?

Due to the sensitivity of data, a limitation could be that growers may not be willing to share this data. Care must be taken to ensure anonymity in the data gathering process.

Data levels and availability
NASS Agricultural Census provides some information about the type of funding farmers are utilizing but hemp specific information is not necessarily available.

Recommendation
Survey instruments should include questions on perceived availability of capital, as well as sources of capital that are known and accessible.

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