Forest Policy and Economics 173 (2025) 103459

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Economic impacts of maple syrup production potential in Kentucky: Input-output analysis

Bobby Thapa [a], Thomas O. Ochuodho [a,*], John M. Lhotka [a], William Thomas [a], Jacob Muller [a], Thomas J. Brandeis [b], Edward Olale [c], Mo Zhou [d], Jingjing Liang [d]

[a] Department of Forestry and Natural Resources, University of Kentucky, Lexington, KY 40546, USA
[b] U.S. Forest Service, Southern Research Station, Forest Inventory and Analysis, Knoxville, TN 37919, USA
[c] Telfer School of Management, University of Ottawa, Ottawa, ON K1N 6N5, Canada
[d] Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907, USA

ARTICLE INFO

Keywords:
Maple syrup
Production
Multiplier effects
Output
Employment

ABSTRACT

Maple syrup has been produced in the United States for centuries. This production has been predominantly in the northeast states. Recent studies indicate promising maple syrup potential beyond the traditional boundaries. This study assesses the economic impacts of potential maple syrup production in Kentucky. Using the input-output analytical framework, likely producer price is considered at three maple syrup production potential levels. At a producer price of $9.48 per liter, the potential total impacts range from 336 jobs and $6.2 million in output at the lower production level to 1356 jobs and $25.05 million in output at the high production level. The potential tax impact of the maple industry ranged from $0.39 million at the lower production level to $1.6 million at the high production level. These results demonstrate the potential of maple syrup production to provide economic benefits to the state through job creation and revenue generation. These results could be used as a basis for favorable policies to support and expand maple syrup production as a viable income source for woodland owners in Kentucky and similar maple producing regions.

1. Introduction

Maple syrup is a natural sweetener made from the sap of maple trees, most commonly sugar (*Acer saccharum* Marsh.) and red (*A. rubrum* L.) maples. Maple syrup production has a rich history in North America (Hinrichs, 1998; Whitney and Upmeyer, 2004; Legault et al., 2019). Traditionally, it was part of rural agricultural activities that contributed to the economy (Houle et al., 2015; Rapp et al., 2019; Snyder et al., 2019). However, over the years, it has become a commercial operation that provides jobs and income to many families in the region (Buchheit et al., 2004; Caughron et al., 2021). It is a labor-intensive activity that provides significant economic benefits to rural communities in the United States (Houle et al., 2015). In 2018, the United States maple industry produced 15.75 million liters (4.16 million gallons) of maple syrup worth $140.6 million at $8.93 per liter ($33.80 per gallon) (NASS, 2018). In the present time, the maple syrup industry has become one of the essential parts of the economy in the states like Vermont, New York, and Maine (Gula, 2023). The annual farm-gate value of maple syrup in the United States is over $150 million (Cannella et al., 2022). Although the business is small in comparison to other commodities, its continued expansion has a favorable economic impact on the Northeast's forested regions (Cannella et al., 2022; Canella and Laughton, 2023). The long-term sustainability of deriving income from the same tree through maple syrup production makes it a unique land use for rural households (Boles, 2019; Snyder et al., 2019).

In the United States, commercial maple syrup production has been mostly confined to the Midwest and Northeast states. Other states such as West Virginia and Kentucky have the potential to extend production beyond these traditional regions (Farrell and Chabot, 2012; Farrell, 2013; Thapa et al., 2024). Kentucky is one of the new frontiers of maple syrup production (Boles, 2019; Hackworth et al., 2024). The state's weather creates conditions that stimulate sap flow, and the abundance of maple trees makes it a potential location for maple syrup production (KMS, 2023). Unlike in northeastern states where the economics of

* Corresponding author.
E-mail addresses: bobby.thapa@uky.edu (B. Thapa), thomas.ochuodho@uky.edu (T.O. Ochuodho), John.Lhotka@uky.edu (J.M. Lhotka), billy.thomas@uky.edu (W. Thomas), Jacob.Muller@uky.edu (J. Muller), thomas.j.brandeis@usda.gov (T.J. Brandeis), eolale@uottawa.ca (E. Olale), mozhou@purdue.edu (M. Zhou), jjliang@purdue.edu (J. Liang).

https://doi.org/10.1016/j.forpol.2025.103459
Received 29 November 2024; Received in revised form 15 February 2025; Accepted 21 February 2025
Available online 3 March 2025

maple syrup production has been well studied and documented with very robust University Extension and Research Centers (examples include Vermont (Becot et al., 2015), Maine (Gabe, 2014), and New York (Epps, 2022)), little is known in more southern states such as Kentucky. Understanding the potential economic impacts is one critical way to gain insights into formulating favorable policies to support growing trees-based activities such as maple syrup production in Kentucky.

Non-timber forest products (NTFPs) like maple syrup are a sustainable way to generate income while maintaining standing forests (Buchheit et al., 2004; Robbins et al., 2008; Frey et al., 2018). In the 1990s and early 2000s, there was increased interest in assessing the economic value, impact, and potential of NTFPs owing to concerns about the impact of timber harvests on endangered species and other conservation priorities (Jones et al., 2021). NTFPs economic impact assessments typically use different economic valuation methods to estimate the direct, indirect, and induced effects of changes in demand for NTFPs on the local economy. There are several theoretical frameworks for conducting economic impact analysis, including input-output (I-O) models, computable general equilibrium models, and social accounting matrices (Okuyama, 2007). I-O models are the most widely used framework because they are relatively straightforward to use and understand (Matheson, 2009; Gretton, 2013). I-O models are based on the idea that every industry in an economy is both a supplier and a consumer of goods and services (Hewings, 1985). The model is constructed by identifying the different industries in an economy and the goods and services they produce. The model then estimates the direct, indirect, and induced effects of changes in demand for each industry on the other industries in the economy (Miller and Blair, 2009; Ochuodho and Alavalapati, 2016). Economic practitioners and policy analysts use Impact Analysis for Planning (IMPLAN), which is the most common input-output analysis tool available today (Joshi et al., 2017).

Despite existing frameworks like I-O analysis and growing interest in expanding maple syrup production to new regions, limited research exists on the economics of maple syrup production outside of the traditional maple-producing areas. In particular, comprehensive studies that assess maple syrup production potential around the country and their economic impacts are missing. Kentucky, despite potential climatic risks on tapping seasons, is a promising location for maple syrup production. However, the existing literature on the potential for maple syrup production in Kentucky has two critical research gaps. Firstly, there is a lack of empirical research on the actual potential for maple syrup production in Kentucky, with most studies relying on anecdotal evidence or expert opinions. Secondly, while existing studies have focused on technical factors such as climatic conditions and tree species, a detailed economic assessment of the potential maple syrup industry in Kentucky is lacking. To address these gaps, this study utilizes maple syrup production potential in Kentucky from a recent study by Thapa et al. (2024). Furthermore, we used I-O modeling to assess the potential economic impacts of maple syrup production in Kentucky at different production potential levels, considering a likely price that could be received by the maple syrup producer.

2. Methodology

2.1. Study area

Kentucky spans a large geographic area and is located just below the traditional maple syrup production region, at a range of latitudes (climates) suitable for maple syrup production. Kentucky is situated in the east-central region of the United States. It has an area of 104,659 km^2 (40,409 mile^2) and a population of 4.5 million people (U.S. CB, 2020). The GDP of Kentucky was $203.3 billion in 2019 (U.S. BEA, 2020). The unemployment rate in Kentucky was 4.2 % in 2019 (U.S. BLS, 2020). According to the Census Bureau, 14.6 % of Kentuckians lived below the poverty line between 2019 and 2021, making Kentucky the state with the sixth-highest poverty rate in the nation. Major industries in Kentucky include manufacturing, agriculture, and tourism (KCED, 2020). According to the U.S.DA FS (2022), Kentucky has an estimated 12.54 million acres of forest cover, with 89 % privately owned forestland, and the dominant tree species being oak, hickory and maple (Oswalt et al., 2022). The climate in Kentucky is generally humid and subtropical with hot summers and mild winters, averaging mid-30s in the winter and mid-80s in the summer (NWS, 2020). Fig. 1 shows the map of the study area.

2.2. Dataset

2.2.1. Maple syrup production level

We used Kentucky's maple syrup production potential data. The methodology to find the maple syrup production potential is explained in detail in recent publication by Thapa et al. (2024) which includes section such as analytical framework, dataset, tests, and model validation and predicting maple syrup yield potential. According to their study: "The inputs for quantifying maple syrup potential were the number of taps (calculated based on Vermont (the highest maple syrup-producing state of the United States) Utilization Rate (VUR)), season length (average of Kentucky's neighboring states of Ohio and West Virginia), total maple trees (sugar and red) greater than or equal to 33cm (13") DBH (FIA database). Then along with these variables, using the climate data (mean of the minimum and maximum temperature), Kentucky maple syrup potential for each county was calculated at the higher end (at 100 % VUR), medium end (at 50 % VUR) and lower end (at 25 % VUR) using the predictive model." In their study, the production potentials of all the counties were summed together as a representation of Kentucky at three distinct levels. The information on all the technical terms, variables, calculations, models, detailed analysis, and results on production potential levels can be found in their study. "Overall, the potential maple syrup production levels in Kentucky were estimated to be approximately 348,236 liters (91,994 gallons) at low potential production level, 698,182 liters (184,440 gallons) at medium potential production level, and 1,403,199 liters (370,686) gallons at high potential production level."

2.2.2. Maple syrup prices

We considered a likely price that could be received by the maple syrup producer when they sell the maple syrup in the market. We used the United States average price per gallon of $9.48 per liter ($35.90 per gallon) as reported by USDA's National Agricultural Statistics Service (NASS) (NASS, 2022). The unit price multiplied by maple syrup quantities (liters) at low, medium, and high potential production levels give total output values (a critical component of economic impact analysis in IMPLAN) at each level as shown in Table 1.

2.2.3. Creating maple syrup industry in social accounting matrix (SAM)

The North American Industry Classification System (NAICS) is a benchmark that federal statistical organizations use to categorize business establishments in Canada, Mexico, and the United States according to the kind of economic activity they carry out. The farming and production of crop products that are not otherwise classified, such as tea, hemp, aloe, and maple syrup, is the primary activity of establishments classified under NAICS code 111998 - all other miscellaneous crop farming. IMPLAN is a platform that integrates huge databases, economic considerations, multipliers, and demographic statistics with a highly detailed, totally customized modeling framework (French, 2018; Khanal et al., 2024). IMPLAN aggregates multiple North American Industry Classification System (NAICS) sectors (or industries) into broader categories to construct its Social Accounting Matrix. Each IMPLAN industry can be directly linked to one or more 6-digit NAICS codes. We used the file that provides the complete 2022 NAICS list and bridges them to IMPLAN's 546 industries and commodities. In IMPLAN, maple syrup production is classified as "all other crop farming" (industry 10), which

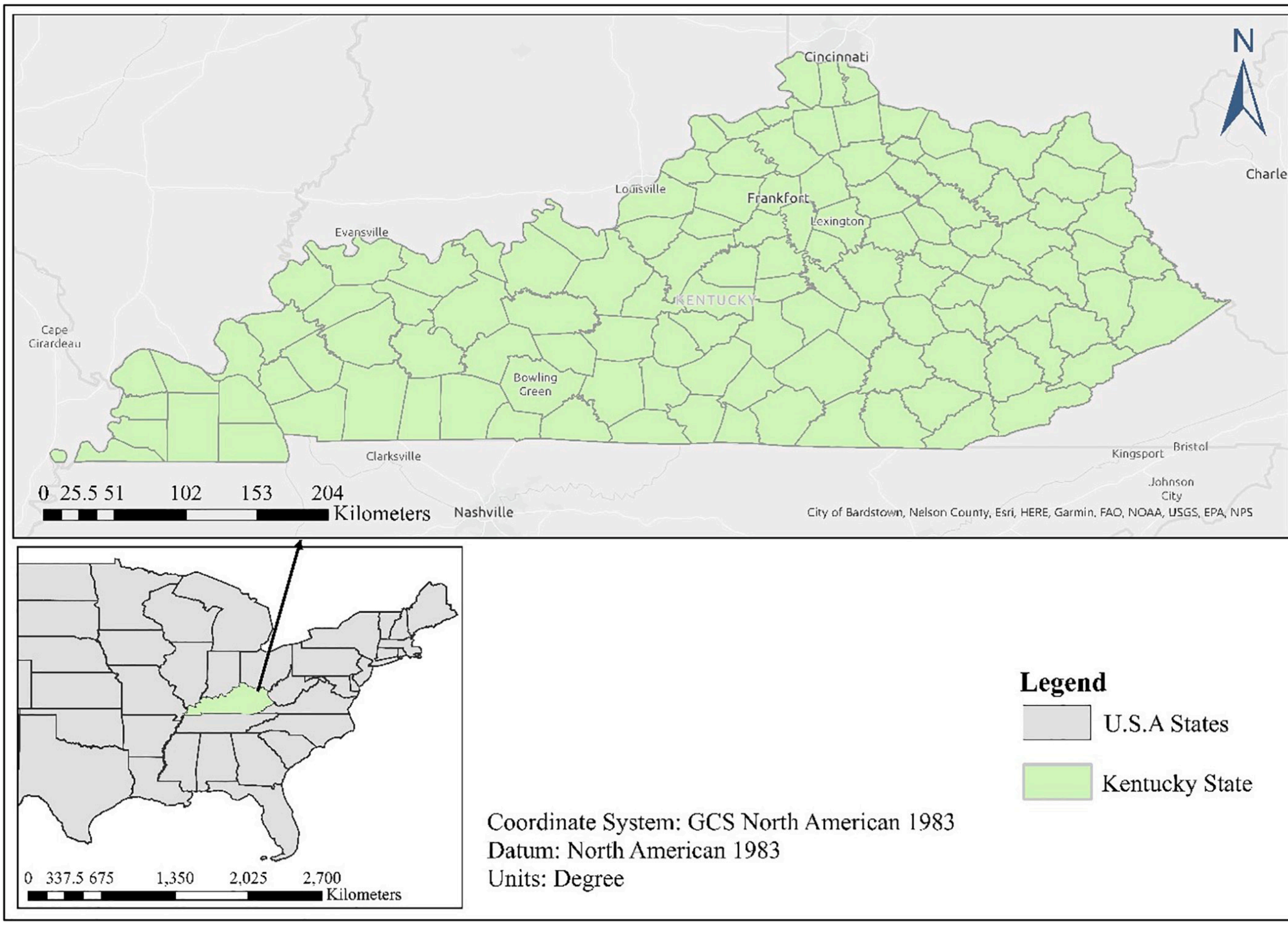

Fig. 1. Map of the study area (Source: Author created using ArcGIS 10.8.1).

Table 1
Potential output values of maple syrup production in Kentucky under low, medium, and high scenarios.

Scenarios	Potential Total Output by Production Level ($)
Low	$3,302,599
Medium	$6,621,403
High	$13,307,632

Table 2
Maple-related sectors in NAICS and industry in IMPLAN.

IMPLAN Description (Code - 10)	NAICS Description (Code - 111998)
All other crop farming	Maple sap concentrating (i.e., producing pure maple syrup in the field)
All other crop farming	Maple sap gathering
All other crop farming	Maple syrup (i.e., maple sap reducing)
All other crop farming	Syrup, pure maple (i.e., maple syrup reducing)

Note: All other crop farming is composed of many crops per the 2022 NAICS to IMPLAN bridge table. For the entire state of Kentucky, this industry is dominated by hay production. The industries are placed together in IMPLAN with an assumption that they follow similar spending pattern.

includes gathering maple sap and producing syrup. Table 2 presents the related IMPLAN industry and NAICS sectors.

2.3. Analysis

We relied on IMPLAN, which works based on the I-O model to measure the total impact upon output, employment, income and value-added when there is a change in the exogenous final demand *f*. I-O multipliers are based primarily on the Leontief inverse (L), which is associated with the exogenous final demand,

$$L = (I - A)^{-1} \tag{1}$$

Where I is the identity matrix and A is the input coefficient matrix (Miller and Blair, 2009; Gim and Kim, 2011). I-O multipliers can be used to assess the regional (or national) economic impacts of an activity. Multipliers are derived from an I-O table or matrix (either regional or rescaled from a national one) (D'Hernoncourt et al., 2011). The model identifies direct impacts by sector and then develops a set of indirect and induced impacts by sector. The fundamental idea is that because all businesses, households, and the government are interconnected through buy-sell agreements, one economic activity can generate a chain reaction of other economic activities throughout the whole economy. IMPLAN's I-O modeling system uses annual regional data to map buy-sell linkages, allowing users to forecast the impact of economic changes or evaluate the influence of previous or current economic activities (Clouse, 2019). The underlying assumptions inherent in the I-O model (Christ, 1955; Clouse, 2021) were recognized and taken into consideration as we conducted our analysis.

2.3.1. Input-output model equations

In this study, we considered the equations used by IMPLAN[1] for different economic indicators and impacts that are presented below.

2.3.1.1. Economic indicators

$$Output = VA + II \tag{2}$$

$$Employment = FT + PT + SL \tag{3}$$

$$Value\ added = EC + PI + OPI + TOPI \tag{4}$$

$$Labor\ income = EC + PI \tag{5}$$

Where *VA* is the value added and *II* is the intermediate inputs. *FT*, *PT* and *SL* are the full-time, part-time, and seasonal employments, *EC* is the employee compensation, *PI* is the proprietor income, *OPI* is the other property income and *TOPI* is the tax on production and imports.

2.3.1.2. Impacts. We studied the potential multiplier effects of the maple syrup industry in Kentucky through the impact (direct, indirect, and induced effects). Direct effects include money spent on salaries, supplies, raw materials, and operating expenses, indirect effects result from supporting sectors (materials, services, energy, labor) purchasing additional inputs to supply the direct industry, and finally, induced effects result from the spending on the daily needs (Henderson et al., 2017).

$$Direct\ effect\ (DE) = TE\ x\ IOC \tag{6}$$

$$Indirect\ effect\ (IE) = TE\ x\ IPO \tag{7}$$

$$Induced\ effect\ (InE) = TE\ x\ IC \tag{8}$$

$$Total\ Effect = DE + IE + InE \tag{9}$$

$$IOC = \frac{Direct\ Output}{Total\ Final\ Demand} \tag{10}$$

$$IPO_{ij} = \frac{Purchases\ by\ Industry\ i\ from\ j}{Total\ Output\ of\ Industry\ j} \tag{11}$$

$$IC = h^{*}c \tag{12}$$

Where,

$$h = \frac{Total\ household\ Income\ generated}{Total\ Output}$$

$$c = \frac{Household\ Consumption\ Expenditures}{Total\ Household\ Income}$$

In above equations, *TE* is the total expenditure in the study area, *IOC* is the industry output coefficient (the amount of output produced by an industry in response to a unit increase in final demand), *IPO* is the inter-industry purchases coefficient (the number of intermediate inputs purchased by maple syrup industry (*i*) in response to a unit increase in output of supporting industry (*j*)), *IC* is the induced coefficient (the change in consumer spending resulting from a change in household income due to a change in economic activity), which incorporates the household income coefficient (*h*) and marginal propensity to consume (*c*).

2.3.2. Scenarios and procedure

When conducting economic impact evaluations in IMPLAN, it is crucial to analyze three fundamental elements, namely the study region, the industry, and the input, as they determine the financial consequences of production changes on local economies (Cheney, 2017). In the new IMPLAN Online Platform, the equations in the above section are implemented using a user-friendly interface that guides the user through the process of defining the study region, selecting the appropriate industry output[2] analysis event, and specifying the final demand vector. The platform then automatically calculates the input-output coefficients, Leontief inverse, and multipliers. Additionally, 2021 IMPLAN-Kentucky data was used for our analysis. This was the most current data release by the time of our analysis. In the end, the results are presented in 2018-dollar value to align with our predicted maple syrup production data. The results are presented in a variety of tables and graphs, allowing the user to easily interpret and communicate the economic impacts of the analysis. In this study, we assessed potential economic impacts considering the likely producer price at the three production potential levels (Table 1) scenarios. The economic impacts were unpacked into economic indicators such as output, value-added, labor income, and employment and economic effects such as direct, indirect, and induced impacts for the three scenarios: producer price-low production level scenario, producer price-medium production level scenario and producer price-high production level scenario.

3. Results and discussion

3.1. Results

We highlighted the results of the potential economic impact assessment. The results are presented in terms of output, value-added and labor income (Fig. 2) and employment (Fig. 3). The total impact results consist of direct, indirect, and induced economic impacts, which are presented in detail in **Appendix Table A.1** under four economic indicators: labor income, employment, value-added and output for each of the three scenarios.

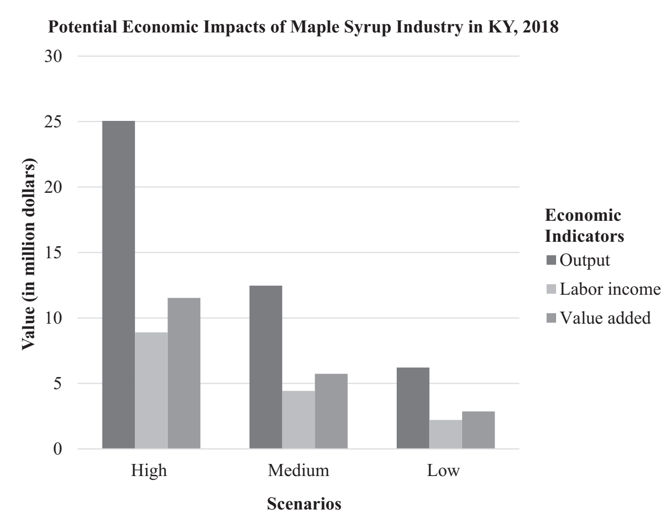

Fig. 2. Economic impacts of maple syrup production potential in Kentucky in terms of output, labor income and value-added.

[1] To learn more on how IMPLAN works and get more understanding of the terms (economic indicators and impacts) used in the equations, look into the article How IMPLAN Works.

[2] The basis for all analysis using the "Industry Output" event type in IMPLAN is output, which is the total amount of production by industry within a given year. Since the output is the overall production value of a sector, it comprises all elements of production value or output for that sector (Clouse, 2019).**Output** = Employee Compensation + Owner Income + Tax on Production and Imports + Other Property Income + Intermediate Inputs.

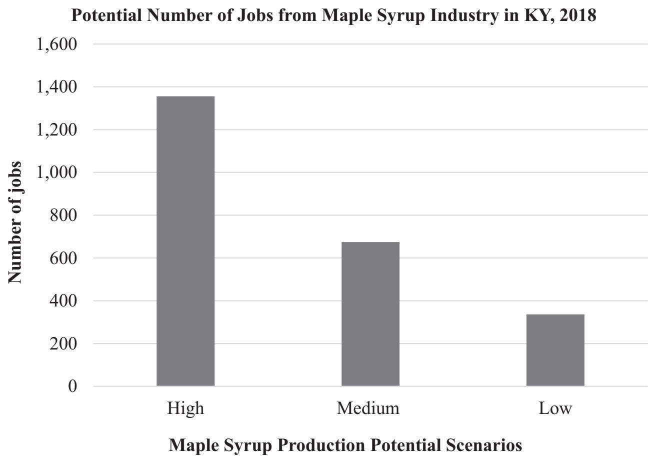

Fig. 3. Employment Impact of Maple Syrup Production Potential in Kentucky.

3.1.1. Economic impacts by indicators

At a selling price of $9.48 per liter, results show a total impact of 1356 jobs, $8.9 million in labor income, $11.5 million in value-added, and $25.1 million in output at the high production level. Similarly total impacts of 675 jobs, $4.4 million in labor income, $5.7 million in value-added, and $12.5 million in output at the medium production level, and total impacts of 336 jobs, $2.2 million in labor income, $2.9 million in value-added, and $6.2 million in output at the low production level.

3.1.2. Taxes

The total tax impact (Fig. 4) includes the sum of direct, indirect, and induced taxes for each level of government taxation: federal, county, sub-county general (city/township), sub-county special district (police, fire, school), and state. The detailed summary of taxes when sold at $9.48 per liter is presented into high, medium, and low production levels (**Appendix Table A.2**). The maple industry paid total taxes of $1.6 million at the high production level, $0.79 million at the medium production level, and $0.39 million at the low production level.

3.2. Discussion

Our assessment of the potential economic impacts of maple syrup production in Kentucky provided information on the industry's potential contribution to employment, value-added, labor income, and total output. Such contributions, if realized, could help diversify Kentucky's economy by supplementing top industries such as agriculture and manufacturing contributions (Bollinger et al., 2018; Peters et al., 2020). The addition of a new maple industry in Kentucky is expected to have significant economic impacts in the state. These impacts can be broadly categorized into three types: direct, indirect, and induced (Becot et al., 2015). The direct impacts of the new industry include the wages paid to workers in the maple industry, the number of new jobs created in the industry, the total value of goods and services produced by the industry, and the output of the industry. For example, the wages paid to production workers, managers, and sales representatives in the maple industry are a direct impact, as is the number of full-time and part-time positions created, the total value of maple products produced, and the output of the industry. The indirect impacts of the new industry are felt in other industries that supply goods and services to the maple industry. These impacts include the wages paid to workers in these industries, the number of new jobs created in these industries, the total value of goods and services produced by these industries, and the output of these industries. For instance, transportation and logistics companies, packaging suppliers, and marketing agencies that supply goods and services to the maple industry will experience indirect impacts such as increased employment and output. The induced impacts of the new industry are felt in industries that benefit from the spending of wages and salaries earned by workers in the maple industry. These impacts include the wages paid to workers in these industries, the number of new jobs created in these industries, the total value of goods and services produced by these industries, and the output of these industries. For example, restaurants, retailers, and healthcare providers that benefit from the spending of wages and salaries earned by workers in the maple industry will experience induced impacts such as increased employment and output.

In the case of taxes, direct taxes are the taxes directly taken from the maple industry by the state, county, etc. Indirect taxes are taxes generated by industries in the directly affected maple industry's supply chain. Induced taxes are taxes generated through spending by households from the money they received in wages in the indirectly and directly affected industries. In our results, the direct taxes by the maple industry to sub-county general, sub-county special district, county, and state levels are negative (**Appendix Table A.2**). This explains that the industry needs more subsidies from the government than to pay taxes. The negative taxes can also be a result when the industry receives tax refunds or when the advantages, they receive surpass the taxes they pay. For these government levels, the indirect and induced taxes are positive. If we look at the federal level, all the direct, indirect, and induced taxes are positive. The overall tax impacts from the maple industry are positive implying an increase in government revenue from taxes.

The potential status of the maple industry in Kentucky compared to other industries in the region may vary depending on several factors, such as the size of the industry, its level of competition, and the overall economic climate in the region. However, it is possible to make some general observations about the relative status of the maple industry compared to other industries in Kentucky based on our numbers. We estimated that if we tap at the high production level and sell the maple syrup at $9.48 per liter then it can create around 1356 jobs, and $25.1 million in output. According to the Kentucky Cabinet for Economic Development, some of the largest industries in Kentucky by the value of output and number of jobs include manufacturing, healthcare, and social assistance followed by retail trade, professional and business services, and agriculture, forestry, fishing and hunting. In 2018, the manufacturing industry contributed a total of $38.67 billion and employed an average of 252,000 people (NAM, 2019). Agriculture, forestry, fishing, and hunting industries added value to the gross domestic product of Kentucky, amounting to around $3.34 billion (Statista, 2023). The potential maple industry in our study can add around $11 million in value added, likely to be a relatively small addition to Kentucky's economy compared to other major industries. However, the maple industry may be an important niche industry in Kentucky,

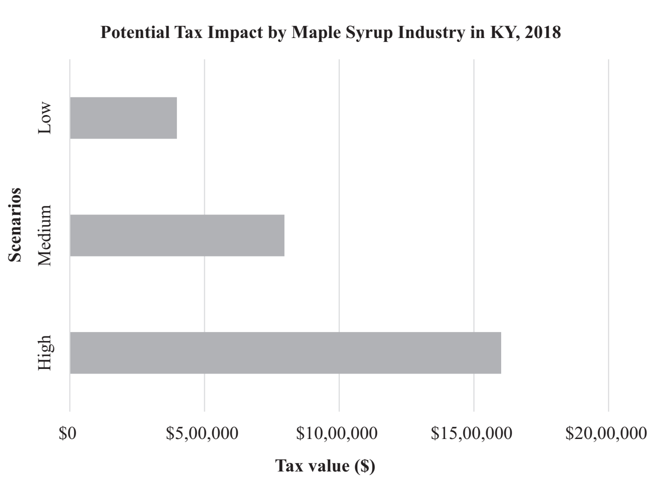

Fig. 4. Total Tax impacts of maple syrup production at three price-production level scenarios.

particularly in areas where maple trees are abundant. This is important where demand for local maple syrup far exceeds supply. In recent years, there has been a growing interest in artisanal and locally produced foods, including maple syrup and other maple products (Velardi et al., 2021). This trend has created opportunities for small-scale maple producers to tap into new markets and differentiate their products based on quality, authenticity, and local sourcing. Moreover, the addition of a new maple industry in Kentucky may have spillover effects on other industries in the region, such as the transportation and logistics industry, the packaging industry, and the retail and service sectors. By creating new demand for goods and services in these industries, the maple industry may help to support job growth and economic activities across a range of sectors in the region. Agritourism could also be enhanced with the addition of maple syrup business. Furthermore, by exploring value-added products such as maple cotton candy, maple-flavored drinks, and maple-coated nuts, the industry can further increase its economic impact. Some producers in Kentucky are already engaged in these value-addition activities. Overall, while the maple industry is likely to be a relatively small industry in Kentucky compared to other major industries, its potential to create new economic opportunities and support job growth in the region should not be overlooked.

While these findings are region-specific, they offer broader insights into the role of niche agricultural industries in fostering economic resilience, a theme of growing global relevance (Trippl et al., 2024; Rana et al., 2024). By situating Kentucky's maple syrup potential within international trends in sustainable agriculture, rural development, and consumer demand for local products, this research contributes to a wider discourse on diversifying economies in regions facing similar climatic, economic, and social conditions and challenges. The framework for analyzing multiplier effects (direct, indirect, and induced impacts) aligns with methodologies used globally to assess niche agricultural diversification (Windfeld and Lhermie, 2022; Alberta Agriculture Forestry, 2020). For example, input-output models have been applied to understanding of the true economic value of agriculture in Canada (Windfeld and Lhermie, 2022), to estimate of the economic importance of the sugar beet industry in Alberta (Alberta Agriculture Forestry, 2020 and specialty crops in developing economies (Miller and Blair, 2009). These studies underscore the value of localized agro-industries in fostering rural resilience-a lesson relevant to regions worldwide seeking sustainable alternatives to traditional agriculture. Interestingly, the maple syrup industry is not only relevant to local economies but also has the potential to appeal to international markets (Wang et al., 2024). As the global demand for natural sweeteners continues to rise, Kentucky's maple syrup could be marketed as a unique southern product, differentiating it from traditional northern varieties. Moreover, the analysis of tax impacts-including negative direct taxes due to subsidies-offers critical lessons for policymakers in regions where nascent industries require public investment to scale (Ghins et al., 2017; Akber and Paltasingh, 2019). Overall, maple syrup production, a sustainable land-use option, aligns with global efforts to support multifunctional agroforestry systems that support ecosystems and economies worldwide.

The findings of this study are relevant to a global audience, particularly in regions considering diversification of forest-based industries. Maple syrup production provides a case study of how non-traditional agricultural industries can contribute to economic resilience and rural development. Similar initiatives have been explored in areas, where traditional forestry sectors are seeking new revenue streams through agroforestry and non-timber forest products (Shanley et al., 2015). Our study contributes to this growing body of research by illustrating how a nascent maple syrup industry can integrate with existing economic structures and generate broader socio-economic benefits.

4. Conclusions

We analyzed the potential economic impacts of the new maple syrup industry in Kentucky (a location with favorable necessities for maple syrup production) under three scenarios, including different production potential levels and likely producer price. The economic impact of the maple industry ranges from an output value of $6.2 million to an output value of $25.1 million. These impact results imply the possibility of maple syrup production in states outside the traditional production states. However, it is important to note that these impact numbers are based on potential levels rather than actual production and therefore do not reflect the current state of the industry in Kentucky. Therefore, actual realization of these numbers is contingent upon engagement of landowners in maple syrup production in areas where enabling factors for maple syrup production are favorable. The industry has the potential to generate output and increase revenue for the state, and these results can guide decisions toward sustainable economic growth in the state. However, it is important to consider any potential risks and challenges such as climate change impacts on tapping season and sanitation issues before investing in the industry. The analysis can assist policymakers and industry stakeholders in making informed decisions about infrastructure and equipment investment, developing value-added products, and promoting the industry to landowners and consumers. Furthermore, recently established Kentucky maple syrup producer's association could be a reliable source of information on this growing industry.

Despite the findings of this study, some limitations are worth noting. Firstly, our analysis is based on assumptions and estimates, and the actual economic impact of a new maple syrup industry may differ from our predictions. Secondly, in the real world, several external factors such as weather conditions, market demand, and government policies can affect the industry's economic impact, which is not accounted for in our study. Additionally, the analysis only considers the economic impacts and does not account for environmental or social impacts. Nonetheless, the analysis provides a useful starting point for understanding the economic impact of the potential maple industry in Kentucky. Given these limitations, we recommend that further research be conducted to refine our estimates and provide a more comprehensive assessment of the potential economic impacts of a new maple syrup industry in Kentucky. This can be done by getting actual on-farm cost data and data on other specific characteristics of the proposed industry. Additionally, future studies could look into any potential negative environmental or ecological impacts of maple syrup production as opposed to traditional forestry focused on timber production. This could entail some cost-benefit analysis between these two forestlands use types. Ultimately, the addition of a new maple industry in Kentucky has the potential to positively impact the local economy by increasing the value of goods and services produced in the region, generating economic activity across various industries, and creating new jobs.

Funding

USDA NRCS funded this research (Grant no.: NR195C16XXXG005). The period covered was from September 17, 2019, to June 30, 2023.

CRediT authorship contribution statement

Bobby Thapa: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis. **Thomas O. Ochuodho:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **John M. Lhotka:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **William Thomas:** Writing – review & editing, Funding acquisition, Conceptualization. **Jacob Muller:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Thomas J. Brandeis:** Writing – review & editing, Funding acquisition, Conceptualization. **Edward Olale:** Writing – review & editing, Software, Methodology. **Mo Zhou:** Writing – review & editing, Funding acquisition, Conceptualization. **Jingjing Liang:** Writing – review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix

Table A.1
Economic impact of potential maple syrup industry in Kentucky, 2018-dollar year at $9.48 per liter ($35.90 per gallon) and different production levels.

Impact	Employment (n)	Labor Income ($)	Value Added ($)	Output ($)
		High Production Level		
1 - Direct	1254	4,833,487	5,286,539	13,307,632
2 - Indirect	64	2,427,162	3,394,475	6,552,594
3 - Induced	38	1,639,953	2,847,516	5,192,624
Total	1356	8,900,602	11,528,530	25,052,851
		Medium Production Level		
1 - Direct	624	2,404,971	2,630,393	6,621,404
2 - Indirect	32	1,207,670	1,688,970	3,260,338
3 - Induced	19	815,982	1,416,823	2,583,665
Total	675	4,428,623	5,736,186	12,465,406
		Low Production Level		
1 - Direct	311	1,199,542	1,311,978	3,302,599
2 - Indirect	16	602,357	842,418	1,626,179
3 - Induced	9	406,993	706,677	1,288,671
Total	336	2,208,892	2,861,073	6,217,448

Table A.2
Modeled taxes paid by the potential maple syrup business in Kentucky, 2018.

			Scenario: Taxes at $9.48 per liter			
Impact	Sub County General	Sub County Special Districts	County	State	Federal	Total
			High Production Level			
Direct	($41,214)	($178,461)	($22,064)	($377,611)	$836,969	$217,618
Indirect	$31,261	$53,786	$10,762	$204,827	$456,856	$757,492
Induced	$29,463	$56,726	$10,330	$197,300	$332,343	$626,162
Total	$19,510	($67,949)	($973)	$24,516	$1,626,168	$1,601,272
			Medium Production Level			
Direct	($20,506)	($88,796)	($10,978)	($187,886)	$416,446	$108,279
Indirect	$15,555	$26,762	$5355	$101,915	$227,315	$376,901
Induced	$14,660	$28,225	$5140	$98,169	$165,362	$311,556
Total	$9708	($33,809)	($484)	$12,198	$809,123	$796,736
			Low Production Level			
Direct	($10,228)	($44,289)	($5476)	($93,713)	$207,713	$54,007
Indirect	$7758	$13,348	$2671	$50,833	$113,380	$187,989
Induced	$7312	$14,078	$2564	$48,965	$82,479	$155,397
Total	$4842	($16,863)	($241)	$6084	$403,571	$397,393

Note: Numbers in brackets indicate negative taxes (subsidies).

Data availability

The authors confirm that the original data used to support this study are available upon request and that certain data are included in the manuscript.

References

Akber, N., Paltasingh, K.R., 2019. Investment, subsidy and productivity in Indian agriculture: an empirical analysis. Agric. Econ. Res. Rev. 32 (conf), 13–25. https://doi.org/10.5958/0974-0279.2019.00014.4.

Alberta Agriculture Forestry, 2020. Economic Impact of Alberta's Sugar Beet Industry. https://open.alberta.ca/dataset/1fb55ce9-3d7d-4c5a-9d62-5694474d7c1a/resource/f8f873c1-c41f-4a3d-8042-a4322c09d96c/download/af-economic-impact-of-albertas-sugar-beet-industry-2020-10.pdf/ (accessed 25 January 2025).

Becot, F., Kolodinsky, J., Conner, D., 2015. The Economic Contribution of the Vermont Maple Industry. Center for Rural Studies at the University of Vermont, Burlington, VT, USA.

Boles, S., 2019. Sweet Equity: Ohio Valley Farmers Tapping Into Tradition. https://wfpl.org/sweet-equity-ohio-valley-farmers-tapping-into-tradition/ (accessed 15 October 2022).

Bollinger, C.R., Hoyt, W.H., Blackwell, D., Childress, M.T., 2018. Kentucky Annual Economic Report 2018. https://uknowledge.uky.edu/cber_kentuckyannualreports/23/.

Buchheit, J.K., Carver, A.D., Zaczek, J.J., Crum, M.L., Mangun, J.C., Williard, K.W.J., Preece, J.E., 2004. Economic feasibility of commercial maple syrup production in Illinois. In: Proceedings, 14th Central Hardwood Forest Conference, pp. 116–121.

Canella, M., Laughton, C., 2023. 2023 Maple Syrup Outlook. Farm Credit East. https://www.farmcrediteast.com/en/resources/Industry-Trends-andOutlooks/Reports/20230301KEP_MapleSyrupOutlook/ (accessed 2 April 2023).

Cannella, M., Cosgrove, T., Laughton, C., 2022. U.S. Economic Forecast | U.S. Maple Syrup Outlook. Volume 16, Issue 5. Knowledge Exchange Partner.

Caughron, A., Legault, S., Haut, C., Houle, D., Reynolds, T.W., 2021. A changing climate in the maple syrup industry: variation in Canadian and USA producers' climate risk perceptions and willingness to adapt across scales of production. Small-Scale For. 20 (1), 73–95. https://doi.org/10.1007/s11842-020-09457-2.

Cheney, P., 2017. 5 Quick "Checks" to Perform on an Economic Impact Analysis. IMPLAN-Support Blog. https://blog.implan.com/fact-checking/ (accessed 18 August 2022).

Christ, C.F., 1955. A Review of Input-Output Analysis. Input-Output Analysis: An Appraisal, pp. 137–182.

Clouse, C., 2019. How IMPLAN Works. IMPLAN-Support Blog. https://support.implan.com/hc/en-us/articles/360038285254-How-IMPLAN (accessed 7 July 2022).

Clouse, C., 2021. Overview of Assumptions of Input-Output Analysis. IMPLAN-Support Blog. https://support.implan.com/hc/en-us/articles/360044458734-Assumptions/ (accessed 7 July 2022).

D'Hernoncourt, J., Cordier, M., Hadley, D., 2011. Input-Output Multipliers – Specification sheet and supporting material, Spicosa Project Report. Université Libre de Bruxelles – CEESE, Brussels. https://doi.org/10.13140/RG.2.2.35295.79529.

Epps, T., 2022. A sweet return: The economic impact of maple season. https://www.wkbw.com/news/local-news/a-sweet-return-the-economic-impact-of-this-years-maple-season/ (accessed 17 October 2022).

Farrell, M.L., 2013. Estimating the maple syrup production potential of American forests: an enhanced estimate that accounts for density and accessibility of tappable maple trees. Agrofor. Syst. 87, 631–641. https://doi.org/10.1007/s10457-012-9584-7.

Farrell, M.L., Chabot, B.F., 2012. Assessing the growth potential and economic impact of the US maple syrup industry. J. Agric. Food Sys. Commun. Dev. 2 (2), 11–27. https://doi.org/10.5304/jafscd.2012.022.009.

French, T., 2018. What is IMPLAN? IMPLAN-Support Blog. https://blog.implan.com/what-is-implan (accessed 28 June 2022).

Frey, G.E., Blatner, K.A., Jacobson, M.G., Downes, C.M.S., Sills, E.O., Mercer, D.E., Lohr, L., 2018. Economics of nontimber forest products. In: Chamberlain, James L., Emery, Marla R., Patel-Weynand, Toral (Eds.), 2018. Assessment of nontimber forest products in the United States under changing conditions. Gen. Tech. Rep. SRS–232. US Department of Agriculture, Forest Service, Southern Research Station, 2018, Asheville, NC, pp. 119–149.

Gabe, T., 2014. Economic impacts of Maine's Maple industry. https://mpra.ub.uni-muenchen.de/id/eprint/65962 (accessed 26 June 2022).

Ghins, L., Mas Aparisi, A., Balié, J., 2017. Myths and realities about input subsidies in sub-Saharan Africa. Dev. Policy Rev. 35, O214–O233. https://doi.org/10.1111/dpr.12258.

Gim, H.U., Kim, K., 2011. Input-output multiplier analysis through the decomposition by factors of the Leontief inverse: a regional case study on the Korean economy. Korean J. Econ. 18 (1), 201–248. https://www.dbpia.co.kr/Journal/articleDetail?nodeId=NODE10952872.

Gretton, P., 2013. On Input-Output Tables: Uses and Abuses, Staff Research Note. Productivity Commission, Canberra. https://www.pc.gov.au/research/supporting/input-output-tables.

Gula, L.T., 2023. Northeast Maple Syrup Season Off to a Very Early Start. http://www.nifa.usda.gov/about-nifa/blogs/northeast-maple-syrup-season-very-early-start (accessed 07 March 2023).

Hackworth, Z.J., Lhotka, J.M., Ochuodho, T.O., Thomas, W.R., 2024. Informing producers in a nontraditional maple syrup region: red maple and sugar maple production parameters in Kentucky. For. Sci. 70 (2), 165–178. https://doi.org/10.1093/forsci/fxae007.

Henderson, J.E., Joshi, O., Tanger, S., Boby, L., Hubbard, W., Pelkki, M., Hughes, D.W., McConnell, T.E., Miller, W., Nowak, J., Becker, C., Adams, T., Altizer, C., Cantrell, R., Daystar, J., Jackson, B., Jeuck, J., Mehmood, S., Tappe, P., 2017. Standard procedures and methods for economic impact and contribution analysis in the forest products sector. J. For. 115, 112–116. https://doi.org/10.5849/jof.16-041.

Hewings, G.J., 1985. Regional Input-Output Analysis. Reprint. Edited by Grant Ian Thrall. WVU Research Repository, 2020. https://researchrepository.wvu.edu/rri-web-book/10/.

Hinrichs, C.C., 1998. Sideline and lifeline: the cultural economy of maple syrup production 1. Rural. Sociol. 63 (4), 507–532. https://doi.org/10.1111/j.1549-0831.1998.tb00690.x.

Houle, D., Paquette, A., Côté, B., Logan, T., Power, H., Charron, I., Duchesne, L., 2015. Impacts of climate change on the timing of the production season of maple syrup in eastern Canada. PLoS One 10. https://doi.org/10.1371/journal.pone.0144844.

Jones, E.T., McLain, R.J., Weigand, J., 2021. Nontimber Forest Products in the United States, 36. Kansas Open Books. https://doi.org/10.17161/1808.32323.

Joshi, O., Henderson, J.E., Tanger, S.M., Boby, L., Pelkki, M., Taylor, E., 2017. A synopsis of methodological variations in economic contribution analyses for forestry and forest-related industries in US South. J. For. 115 (2), 80–85.

Kentucky Cabinet for Economic Development (KCED), 2020. Kentucky's Major Industries. https://ced.ky.gov/existing_industries/Major_Industries.

Kentucky Maple Syrup (KMS), 2023. About Maple Syrup. Retrieved from. https://ky-maplesyrup.ca.uky.edu/about-maple-syrup (accessed 05 March 2023).

Khanal, N., Pokharel, R., Poudel, J., Gc, S., Shannon, E., Huff, E., Finley, A., 2024. Analysis of location, feedstock availability, and economic impacts of potential mass timber processing facilities in Michigan. Forest Policy Econ. 163, 103203. https://doi.org/10.1016/j.forpol.2024.103203.

Legault, S., Houle, D., Plouffe, A., Ameztegui, A., Kuehn, D., Chase, L., Blondlot, A., Perkins, T.D., 2019. Perceptions of US and Canadian maple syrup producers toward climate change, its impacts, and potential adaptation measures. PLoS One 14 (4), e0215511. https://doi.org/10.1371/journal.pone.0215511.

Matheson, V., 2009. Economic multipliers and mega-event analysis. Int. J. Sport Financ. 4 (1), 63–70. https://crossworks.holycross.edu/econ_working_papers/104/.

Miller, R.E., Blair, P.D., 2009. Input-Output Analysis: Foundations and Extensions, Second edition. Cambridge University Press, New York.

National Association of Manufacturers (NAM), 2019. Kentucky Manufacturing Facts. https://www.nam.org/state-manufacturing-data/2019-kentucky-manufacturing-facts/ (accessed 11 November 2022).

National Weather Service (NWS), 2020. Kentucky Climate Summary. https://www.weather.gov/lmk/climate_summary (accessed 16 April 2022).

Ochuodho, T.O., Alavalapati, J.R., 2016. Integrating natural capital into system of national accounts for policy analysis: an application of a computable general equilibrium model. Forest Policy Econ. 72, 99–105. https://doi.org/10.1016/j.forpol.2016.06.020.

Okuyama, Y., 2007. Economic modeling for disaster impact analysis: past, present, and future. Econ. Syst. Res. 19 (2), 115–124. https://doi.org/10.1080/09535310701328435.

Oswalt, C.M., Brandeis, T.J., Oswalt, S.N., 2022. Kentucky's forests, 2014 (with updates for 2016). In: Resour. Bull. SRS 233. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, NC. https://doi.org/10.2737/SRS-RB-233, 44 p.

Peters, J., Huish, R., Taylor, D., Munson, B., 2020. Comparative analysis of four maple species for syrup production in south-central Appalachia. J. Agric. Food Syst. Commun. Dev. 9 (2), 267–276. https://doi.org/10.5304/jafscd.2020.092.015.

Rana, J.C., Bisht, I.S., Mathur, P., Fadda, C., Mittra, S., Ahlawat, S.P., Vishwakarma, H., Yadav, R., 2024. Involving rural youth in agroecological nature-positive farming and culinary agri-ecotourism for sustainable development: the Indian scenario. Sustainability 16 (21), 9417. https://doi.org/10.3390/su16219417.

Rapp, J.M., Lutz, D.A., Huish, R.D., Dufour, B., Ahmed, S., Morelli, T.L., Stinson, K.A., 2019. Finding the sweet spot: shifting optimal climate for maple syrup production in North America. For. Ecol. Manag. 448, 187–197. https://doi.org/10.1016/j.foreco.2019.05.045.

Robbins, P., Emery, M.R., Rice, J.L., 2008. Gathering in Thoreau's backyard: nontimber forest product harvesting as practice. Area 40 (2), 265–277. https://doi.org/10.1111/j.1475-4762.2008.00794.x.

Shanley, P., Pierce, A.R., Laird, S.A., Binnqüist, C.L., Guariguata, M.R., 2015. From lifelines to livelihoods: non-timber forest products into the twenty-first century. Trop. For. Handb. 1-50. https://doi.org/10.1007/978-3-642-41554-8_209-1.

Snyder, S.A., Kilgore, M.A., Emery, M.R., Schmitz, M., 2019. Maple syrup producers of the Lake States, USA: attitudes towards and adaptation to social, ecological, and climate conditions. Environ. Manag. 63 (2), 185–199. https://doi.org/10.1007/s00267-018-1121-7.

Statista, 2023. GDP by Industry Kentucky U.S. 2022. https://www.statista.com/statistics/1064968/kentucky-real-gdp-by-industry/ (accessed 28 January 2023).

Thapa, B., Ochuodho, T.O., Lhotka, J.M., Thomas, W., Hackworth, Z.J., Muller, J., Brandeis, T.J., Olale, E., Zhou, M., Liang, J., 2024. Assessing the factors affecting maple syrup yield in the US and predicting production potential in Kentucky. Trees For. People 100649. https://doi.org/10.1016/j.tfp.2024.100649.

Trippl, M., Fastenrath, S., Isaksen, A., 2024. Rethinking regional economic resilience: preconditions and processes shaping transformative resilience. Eur. Urban Reg. Stud. 31 (2), 101–115. https://doi.org/10.1177/09697764231172326.

U.S. Bureau of Economic Analysis (BEA), 2020. Gross Domestic Product by State, 2019. https://www.bea.gov/data/gdp/gdp-state (accessed 16 April 2022).

U.S. Bureau of Labor Statistics (BLS), 2020. State and Area Employment, Hours, and Earnings. https://www.bls.gov/regions/mid-atlantic/news-release/unemployment_kentucky.htm. /(accessed 16 April 2022).

U.S. Census Bureau (CB), 2020. Kentucky QuickFacts. https://www.census.gov/quickfacts/KY (accessed 16 April 2022).

USDA Forest Service (FS), 2022. Forests of Kentucky, 2019. Resource Update FS-388. U. S. Department of Agriculture, Forest Service, Asheville, NC. https://doi.org/10.2737/FS-RU-388, 2p. (accessed July 27, 2023).

USDA NATIONAL AGRICULTURAL STATISTICS SERVICE (NASS), 2018. United States Maple Syrup Production. https://www.uvm.edu/sites/default/files/Agriculture/maple-nass-2018.pdf. /(accessed 07 October 2021).

USDA National Agricultural Statistics Service (NASS), 2022. Maple Syrup Production. News Release. https://www.nass.usda.gov/Statistics_by_State/Michigan/Publications/Current_News_Release/2022/nr2233mi.pdf.

Velardi, S., Leahy, J., Collum, K., McGuire, J., Ladenheim, M., 2021. Adult learning theory principles in knowledge exchange networks among maple syrup producers and beekeepers in Maine. J. Agric. Educ. Ext. 27 (1), 3–20. https://doi.org/10.1080/1389224X.2020.1773283.

Wang, Q., Cannella, M., Zou, Y., 2024. China's emerging market for maple syrup: opportunities and challenges for US exports. J. Food Distrib. Res. 55 (1), 46–61.

Whitney, G.G., Upmeyer, M.M., 2004. Sweet trees, sour circumstances: the long search for sustainability in the North American maple products industry. For. Ecol. Manag. 200 (1–3), 313–333. https://doi.org/10.1016/j.foreco.2004.07.006.

Windfeld, E., Lhermie, G., 2022. The value of Canadian agriculture: direct, indirect, and induced economic impacts. Front. Sustain. Food Syst. 6. https://doi.org/10.3389/fsufs.2022.940968.