

ECOLOGICAL FOOTPRINT AND BIOCAPACITY RESEARCH AGENDA Edition 2

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Presented to the Science Advisory Committee on August 12, 2024
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SUMMARY

At the June 2nd, 2023, Science Advisory Committee (SAC) meeting, a research brief was presented that included 14 research topics to assist in setting the SAC research priorities. The research topics were selected based on previous discussions at SAC meetings, the priority-setting exercise, data analyst experience, and partnership grants. In February 2024, a list of research questions was devised to set the International Ecological Footprint Learning Lab (IEFLL) research priorities. These research questions were presented to IEFLL co-directors and students in the 2023-2024 cohort. These research questions were selected based on the IEFLL research agenda, discussions with IEFLL members, and research-in-progress. This document combines the SAC research brief and the IEFLL research questions into one document to present to SAC at the August 12, 2024 meeting. Combining these documents aims to update SAC about what research is being addressed and allow SAC to decide what research should be prioritized.

The research questions are organized into three groups based on their completion. The first group of questions are underway. The second group of questions has been thought out, while the last group consists of questions that will be explored in the future. In addition to the groupings of these questions, there are also different categorizations of the research questions. The first way these research questions are categorized is by the four thematic research areas in IEFLL (1) metrics and modelling, (2) national applications, (3) community applications, and (4) responsive scaling. These research areas are intended to be broad in scope and allow for overlap. The metrics and modelling area concerns understanding the possibilities and constraints related to economics, sustainability, well-being, development, and sustainability goals including net-zero emissions. The national applications area relates to questions about economic and social accounts, policy, international trade, multilateral conventions, and sustainability goals. The community applications area relates to individuals and groups of people to understand how the data we generate, apply and communicate can be useful for affecting outcomes. The fourth area, responsive scaling, concerns data and metrics relatable at different geographic scales and social aggregations and attributions. Additionally, to incorporate advances in geomatics earth observation data.

The research questions have also been categorized based on their expected time of completion. Varying from 6 months to 2 years. This indicates what students can take on the research. A third way of categorizing the research questions is by Ecological Footprint and Biocapacity component. This relates to what component is impacted by or relates to the research question. Not all of the research questions have a direct impact on specific components, rather have a relationship to certain components. Another way that these research questions are being categorized is by their purpose for Ecological Footprint and Biocapacity methodologies. There are three purposes identified, (1) refining the existing framework, (2) expanding on the existing framework, and (3) increasing the applicability. The framework refers to the current methodology used for calculating Ecological Footprint and Biocapacity. Refining the framework refers to improvements in the current methodology. Expanding the framework refers to innovations to the current methodology, such as something new being added in.

Increasing the applicability refers to expanding the legitimacy, relevancy, and suitability of Ecological Footprint and Biocapacity methodologies.

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Research Questions Being Investigated:

1. Investigating new data sources for built-up land:
2. Adding Ecological Footprint into Macroeconomic Modelling Technologies
3. Inclusion of marine mammals and marine megafauna in the fishing grounds component
4. Improved incorporation of life cycle data to estimate the impacts of traded commodities
5. How can remote sensing imagery and data be incorporated into Ecological Footprint and Biocapacity methodology to improve the data and spatial resolution, particularly the built-up land component? How can this help with sub-national derivations of Biocapacity?

Thought-Out Research Questions: Not yet being investigated

1. Revise the Average Forest Carbon Sequestration rate in the national accounts:
2. Derive spatially explicit equivalence factors:
3. Revise the data source/approach to deriving forest Biocapacity:
4. Include wetlands (and/or other land cover types) as providing Biocapacity:
5. Include other Greenhouse gasses in the National Ecological Footprint and Biocapacity Accounts:
6. Investigating how carbon footprint and ocean sequestration align with other global reporting metrics:
7. Creating the methodology blueprint of community-specific Ecological Footprint calculators:
8. Generating Ecological Footprint metrics that align with the System of Environmental and Economic Accounting (SEEA):
9. What is the relationship between biodiversity and Biocapacity? Can Biocapacity be used to measure the impacts on Biodiversity?

To be Explored Research Questions:

1. How can the built-up land component be adapted to account for the multiple ecosystem services provided by urban green spaces within built-up land?
2. How well do equivalence factors apply across multiple scales, and time, when comparing Biocapacity between regions and countries?
3. How do different types of land use and land ownership affect the Ecological Footprint and Biocapacity ratio among countries? What are the most effective spatial analysis techniques for examining land-use change and ownership?
4. How can the inclusion of stocks in Ecological Footprint and Biocapacity accounting

improve the methodology? Will this improve the comparability of the results between different countries and regions?

5. What are the most effective methods for localized data gathering and reconciliation with regional data, to support the use of the Ecological Footprint and Biocapacity in municipal and sub-national planning and policy development?

6. In what ways can the narrative of Ecological Footprint and Biocapacity, particularly the National Accounts, be reframed to increase engagement and understanding?

7. What is the proportion of the Ecological Footprint of Consumption by tourists compared to residents in countries that have high tourism levels?

8. Creation of a database of embodied Ecological Footprint for man-made materials

9. Deriving a nutrition index for other commodities, beyond cereals, for the cropland component of Ecological Footprint

Research Questions Summary Table (24 Total)

See the summary table in Google Sheets [via this link](#).

Stage of Research	RQ	Estimated Time	Main IEFL Research Area	Secondary IEFL Research Area	Impacts on EF/B Compon.	Research Purpose
RQ being Invest.	Investigating new data sources for built-up land	6-12 months	National Applications		Built-up land of B	Refining the existing framework
RQ being Invest.	Adding EF to macroeconomic modelling	6-12 months	Metrics and modelling		All EF components	Increasing the applicability
RQ being Invest.	Including marine mammals in fishing grounds	6 months	National Applications		Fishing grounds of EF	Expanding the existing framework
RQ being Invest.	How can remote sensing data be added to B?	6-12 months	National Applications	Responsive Scaling	All EF & B components	Expanding the existing framework
RQ being Invest.	Improved incorporation of life cycle data in EF	6-12 months	National Applications		Carbon of EF	Refining the existing framework
Thought-Out RQ	Revise the average forest carbon sequestration rate	6-12 months	National Applications		All EF components	Refining the existing framework
Thought-Out RQ	Derive spatially explicit equiv. factors	6-12 months	National Applications	Responsive Scaling	All EF & B components	Refining the existing framework

Stage of Research	RQ	Estimated Time	Main IEFL Research Area	Secondary IEFL Research Area	Impacts on EF/B Compon.	Research Purpose
Thought-Out RQ	Revise the data source/approach for forest Biocap.	1-2 years	National Applications	Responsive Scaling	Forest of B	Refining the existing framework
Thought-Out RQ	Include wetlands (and/or other land types) for Biocap.	6-12 months	National Applications	Responsive Scaling	(new) Wetlands of B	Expanding the existing framework
Thought-Out RQ	Include other GHGs	6-12 months	National Applications	Responsive Scaling	Carbon of EF	Expanding the existing framework
Thought-Out RQ	Investigate how carbon footprint & ocean sequestration align with global reporting metrics	6 months	Metrics and modelling	National Applications	All EF components	Increasing the applicability
Thought-Out RQ	Create methods blueprint for community-specific EF calculators	6-12 months	Community Applications		All EF components	Increasing the applicability
Thought-Out RQ	Generate EF metrics aligning with SNA/SEEA	1-2 years	Metrics and modelling	National Applications	All EF & B components	Increasing the applicability

Stage of Research	RQ	Estimated Time	Main IEFL Research Area	Secondary IEFL Research Area	Impacts on EF/B Compon.	Research Purpose
Thought-Out RQ	Determining the relationship between Biocapacity & biodiversity	6-12 months	National Applications	Responsive Scaling	All B components	Increasing the applicability
Thought-Out RQ	What is the capacity of intensively managed ecosystems to provide specific goods and services?	6-12 months	National Applications	Responsive Scaling	Cropland, Fishing Grounds, Grazing land, and Forest land of Biocapacity	Refining the existing framework
To be explored RQ	How can built-up land account for ES in urban spaces?	6-12 months	National Applications	Responsive Scaling	Built-up land of B	Refining the existing framework
To be explored RQ	How well does EQF apply across multiple scales and times?	6 months	National Applications	Responsive Scaling	All B components	Refining the existing framework
To be explored RQ	How can spatial analysis be used to examine land-use change?	6 months	Responsive Scaling	Community Applications	All EF & B components	Expanding the existing framework

Stage of Research	RQ	Estimated Time	Main IEFL Research Area	Secondary IEFL Research Area	Impacts on EF/B Compon.	Research Purpose
To be explored RQ	How can stocks be included in EFB methods?	1-2 years	National Applications	Responsive Scaling	All EF & B components	Expanding the existing framework
To be explored RQ	What are the most effective methods for localized data gathering for EFB methods?	6-12 months	Responsive Scaling	National Applications	All EF & B components	Increasing the applicability
To be explored RQ	How can the EFB narrative be reframed to increase engagement & understanding?	6 months	National Applications	Community Applications	All EF & B components	Increasing the applicability
To be explored RQ	What proportion of EFc is from tourists vs. residents?	6-12 months	Responsive Scaling	National Applications	All EF components	Expanding the existing framework
To be explored RQ	Create a database of embodied EF for man-made materials	1-2 years	Metrics and modelling	Responsive Scaling	All EF components	Increasing the applicability
To be explored RQ	Derive a nutrition index beyond cereals	6-12 months	National Applications		Cropland of EF	Refining the existing framework

Research Questions Being Investigated:

1. Investigating new data sources for built-up land:

Estimated research time: 6-12 months

IEFLL research area: national applications

Component affects: the built-up land component of Biocapacity

Research purpose: refining the existing framework

Skills needed for research: quantitative methods skills, MySQL workbench and command line, EFB methods knowledge

IEFLL Partner(s) involved: York University EFI (Eric Miller)

Researcher(s): Peri Dworatzek, Sandy Kazubowski-Houston, Anne Van Berkum

Currently, the national Ecological Footprint and Biocapacity accounts use three data sources for the built-up area; Global Agro-Economic Zones (GAEZ), Global Land Cover (GLC), and Corine Land Cover (CLC). There are a couple of limitations to these datasets: none of them have continued timeline data. GLC and GAEZ only have data for the year 2000, and the remaining years from 1961-1999, and 2001-present are interpolated based on population. CLC has data for four years; 2000, 2006, 2012, and 2018 and the rest of the years follow the same interpolation process as GAEZ and GLC. The CLC dataset applies to 38 European countries, GAEZ applies to 163 countries, and GLC applies to 217 countries. The use of the datasets is prioritized in that order. Another limitation of this current methodology is that each dataset has varying results for countries, sometimes with substantial differences. Researching new data source(s) and implementing them into the Accounts could improve the built-up area component of Biocapacity by reducing the need for interpolation. Depending on the data sources, this might require GIS skills.

This would impact the built-up land component of Biocapacity because it could have a change in the hectares of land for the built-up area. There would be varying effects for all countries on the whole timeline, depending on how different the new data source is from the current sources.

2. Adding Ecological Footprint into Macroeconomic Modelling Technologies

Estimated research time: 6-12 months

IEFLL research area: metrics and modelling

Impacts on EFB components: relating to all Ecological Footprint and Biocapacity components

Research purpose: increasing applicability of the work

Skills needed for research: macro modelling skills, quantitative methods, coding

IEFLL Partner(s) involved: Peter Victor (York University)

Researcher(s): Andrew Reeves

Macroeconomic models are important analytical tools to understand issues in certain economies and countries. Some examples of models include agent-based models, supply chain

models, and stock-flow consistent models. Including Ecological Footprint as a parameter in macroeconomic models would improve the model's results to become more holistic and comprehensive.

This research relates to all components of Ecological Footprint and Biocapacity, not directly impacting specific components. This requires a high level of effort as expertise in macroeconomic modelling and footprint methodologies would be required. Additionally, experience working with spreadsheets, databases, and quantitative research methods is important.

3. Inclusion of marine mammals and marine megafauna in the fishing grounds component

Estimated research time: 6 months

IEFLL research area: national applications

Impacts on EFB components: fishing grounds component of Ecological Footprint

Research purpose: expanding the existing framework

Skills needed for research: ecology/biology knowledge, EFB methods knowledge

IEFLL Partner(s) involved: York University, University of Iceland

Researcher(s): Kiona Lo

Currently, marine mammals such as dolphins and whales and other marine megafauna such as alligators are not included in the fishing grounds component of the National Ecological Footprint and Biocapacity Accounts. To include these species in the National Accounts, research needs to be done to determine the trophic levels and other relevant parameters to be able to convert mass (or number of mammals to mass) to the quantity of biomass these large species consume, to how much aquatic footprint they embody.

Following the NFA Guidebook, the mean trophic levels for individual species are used first and group trophic levels are used only if the mean trophic levels are not available. Fishbase is the source of trophic levels for fish species in the National Accounts that does not have trophic levels for marine mammals and some marine megafauna. Seale Base, a global online database of information about marine life, is a potential data source for trophic levels of other species.

Trites, A. W. (2019). Marine mammal trophic levels and trophic interactions. Encyclopedia of Ocean Sciences. Elsevier, 589-594.

Pauly, D., Trites, A. W., Capuli, E., & Christensen, V. (1998). Diet composition and trophic levels of marine mammals. ICES journal of Marine Science, 55(3), 467-481.

Bode, A., Saavedra, C., Álvarez-González, M., Arregui, M., Arbelo, M., Fernández, A., ... & Santos, M. B. (2022). Trophic position of dolphins tracks recent changes in the pelagic ecosystem of the Macaronesian region (NE Atlantic). Marine Ecology Progress Series, 699, 167-180.

Jota Baptista, C., Seixas, F., Gonzalo-Orden, J. M., & Oliveira, P. A. (2022). Biomonitoring of heavy metals and metalloids with wild mammals in the Iberian Peninsula: a systematic review. *Environmental Reviews*, 31(1), 66-75.

4. Improved incorporation of life cycle data to estimate the emissions embodied in traded commodities

Estimated research time: 6-12 months

IEFLL research area: national applications

Impacts on EFB components: relating to the carbon component of EF

Research purpose: refining the existing framework

Skills needed for research: EFB methods knowledge, MySQL workbench and command-line skills, quantitative skills

IEFLL Partner(s) involved: York University (EFI), Eric Miller

Researcher(s): Matt Dyck

The current approach to estimating the carbon emissions of traded commodities is to take the embodied energy for traded commodities estimated by using a mixture of data from ecoinvent, independent LCAs, and other online tools (Lin et al., 2019). A global emission factor for primary energy production is applied to the embodied energy for each commodity to estimate the total CO₂ embodied in the exported and imported trade for each country. These CO₂ emissions are linked to global hectares by the amount of forest land required to sequester the emissions, normalized by yield and equivalence factors.

Better incorporating life cycle assessment data and utilizing life cycle impact assessment methods in the accounts could help overcome several of these challenges in the future. Namely, matching the commodities in Comtrade to corresponding processes in the ecoinvent database by HS code would make it possible to assess their total embodied GHG emissions, freshwater consumption, and other environmental impacts with more geographically representative characterization factors by using life cycle impact assessment methods like ReCiPe2016.

Lin, D., Hanscom, L., Martindill, J., Borucke, M., Cohen, L., Galli, A., Lazarus, E., Zokai, G., Iha, K., & Wackernagel, M. (2019). Working guidebook to the national footprint and biocapacity accounts. Global Footprint Network.

https://www.footprintnetwork.org/content/uploads/2019/05/National_Footprint_Accounts_Guidebook_2019.pdf

5. How can remote sensing imagery and data be incorporated into Biocapacity methodology to improve the data and spatial resolution, particularly the built-up land component? How can this help with sub-national derivations of Biocapacity?

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to all B components

Research purpose: expanding the existing framework

Skills needed for research: GIS and geomatics skills, EFB methods knowledge, MySQL workbench and command-line skills, quantitative skills

IEFLL Partner(s) involved: York University (EFI)

Researcher(s): Anne Van Berkum

Currently, the land area data is taken in CSV format and is not spatially explicit data used in geomatics software. The land data is taken from a few sources, the Food and Agriculture Organization of the United Nations (FAOSTAT), specifically from their Resourcestat database; the Global Agro-Eco Zones database; the Global Land Cover database; and the Corine database. There can be improvements made to the National Accounts by using remote sensing imagery and other geospatial data sources. This would improve the resolution of the data giving more details about the land-use.

Thought-Out Research Questions: Not yet being investigated

1. Revise the Average Forest Carbon Sequestration rate in the national accounts:

Estimated research time: 6-12 months

IEFLL research area: national applications

Impacts on EFB components: all components of the Ecological Footprint

Research purpose: refining the existing framework

Skills needed for research: quantitative methods, EFB methods knowledge, MySQL workbench, and MySQL command line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

The Average Forest Carbon Sequestration (AFCS) rate measures the global average amount of carbon that can be sequestered through photosynthesis from a hectare of forests. This metric is the most influential parameter used to convert carbon dioxide emissions into global hectares in the national Ecological Footprint and Biocapacity accounts. The current calculation uses data on the yearly average biomass growth of forests and global forested areas. This data comes from the Intergovernmental Panel on Climate Change and the Food and Agriculture Organization of the United Nations respectively. The current methodology examines a range of AFCS values that are created using multiple calculation options each with different input variables. This variability is meant to reflect the capacity of carbon sequestration by forests depending on the level of human management. The methodology applies the latest update published by Mancini, MS., et al (2016) that follows recommendations by Kitze et al. (2009). Updated or alternative sources or methodologies could help to ensure that this rate reflects the best available science throughout the timeline from 1961 to the present.

If the methodology behind the AFCS rate were to be changed, it would have effects on all components of the Ecological Footprint to varying degrees over the full timeline. The beginning stages of this research would require skills to source alternative data and some knowledge of working with spreadsheets and data. The later stages would require someone to

be deeply knowledgeable of footprint methodologies, MySQL workbench, and MySQL command line to be able to devise and implement the new data and methodology.

Kitzes, Justin, and Mathis Wackernagel. "Answers to Common Questions in Ecological Footprint Accounting." *Ecological Indicators* 9, no. 4 (July 2009): 812–17.
<https://doi.org/10.1016/j.ecolind.2008.09.014>.

Mancini, Maria Serena, Alessandro Galli, Valentina Niccolucci, David Lin, Simone Bastianoni, Mathis Wackernagel, and Nadia Marchettini. "Ecological Footprint: Refining the Carbon Footprint Calculation." *Ecological Indicators* 61 (February 2016): 390–403.
<https://doi.org/10.1016/j.ecolind.2015.09.040>.

2. Derive spatially explicit equivalence factors:

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: all components of Ecological Footprint and Biocapacity

Research purpose: refining the existing framework

Skills needed for research: quantitative methods, EFB methods knowledge, MySQL workbench, and MySQL command line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Equivalence Factor (EQF) is a key indicator for calculating Ecological Footprint and Biocapacity. It represents the ratio of the biological productivity of different forms of Biocapacity to a global average hectare of biologically productive land. It is a necessary factor to derive commensurable units of global hectares. Currently, the Global Agro-Ecological Zones dataset is used, a global spatially explicit dataset of agricultural suitability. This model divides all land into five categories based on the potential crop productivity, giving each land a qualitative suitability index. More details on the methodology for deriving EQF can be found in Borucke et al. (2013). Two opportunities exist for improvement: 1) derive a spatially explicit calculation of EQF based on the current GAEZ dataset; 2) search for an alternative data source.

If the EQF calculation is modified there are expected to be effects on all the components of Ecological Footprint and all components of Biocapacity, for all countries to varying degrees over the full timeline. The beginning stages would require skills to source alternative data, work with spreadsheets and databases, and potentially use geospatial software. The later stages would require someone to be deeply knowledgeable of footprint methodologies, MySQL workbench, and MySQL command line to be able to devise and implement the new data and methodology.

Borucke, Michael, David Moore, Gemma Cranston, Kyle Gracey, Katsunori Iha, Joy Larson, Elias Lazarus, Juan Carlos Morales, Mathis Wackernagel, and Alessandro Galli. "Accounting for Demand and Supply of the Biosphere's Regenerative Capacity: The National Footprint Accounts' Underlying Methodology and Framework." *Ecological Indicators* 24 (January 2013): 518–33. <https://doi.org/10.1016/j.ecolind.2012.08.005>.

3. Revise the data source/approach to deriving forest Biocapacity:

Estimated research time: 1-2 years

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: Forest land component of Biocapacity

Research purpose: refining the existing framework

Skills needed for research: geomatics skills, EFB methodologies, MySQL workbench and command line, quantitative skills

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Forest Biocapacity represents the bio-productivity of forest land. The current methodology uses the Net Annual Increment (NAI) of underbark wood to represent productivity that matches well with the harvest of forest products, which can also be represented as tonnes or cubic meters of wood. There are several issues with this: 1) NAI does not appear to have strong support moving forward as a globally reported dataset, 2) it is not reported in a full-time series, and 3) NAI is associated with commercially viable forests and does not represent the productivity of all forest in a country. Therefore, forest Biocapacity is strongly skewed to capture the productivity of the commercially viable forest in a country. A spatially explicit analysis could be used to calculate the relative productivity of forests by country. Additionally, an opportunity exists for incorporating research related to Human Appropriation of Net Primary Productivity to understand how forest Biocapacity is changing over time by the influence of human activities.

If the source/approach is modified for calculating forest Biocapacity this will be the Forest land component of Biocapacity. This requires the individual to have geomatics skills, expertise in spatially explicit analysis, footprint methodologies, MySQL workbench, and MySQL command line. Additionally, this potentially will require computation-heavy analysis as there are large messy volumes of data.

4. Include wetlands (and/or other land cover types) as providing Biocapacity:

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: potentially a new component for wetlands

Research purpose: expanding the existing framework

Skills needed for research: quantitative skills, EFB methods knowledge, MySQL workbench and command line, geomatics skills

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Currently, the national Ecological Footprint and Biocapacity accounts do not include wetlands as a component within Biocapacity. Researchers at the Ecological Footprint Initiative implemented a wetlands component within Biocapacity for the Ontario Ecological Footprint and Biocapacity report (Miller et al., 2021). This proof-of-concept design can be used as a starting point for further research on including wetlands in the national Ecological Footprint and Biocapacity accounts. Research would be needed to find a global database with national

accounts of wetland areas area over time. One potential data source could be the Global Lakes and Wetlands Database. Research would also be needed to develop a method to calculate wetland Biocapacity. The Biocapacity of wetlands would presumably be limited to carbon uptake since they are not globally significant sources of food for humans and livestock. A resulting revision to the Accounts could be to name the footprint's carbon component as "terrestrial carbon uptake" and include in Biocapacity an account of "wetland" or "wetland carbon uptake".

This research would affect the total Biocapacity of all countries to varying degrees over the full timeline, by adding a new component to Biocapacity. In the beginning stages of research, the student will design the research scope, source new data, and work with spreadsheets and databases. Then towards the later stages, they will devise the implementation of the data and how it will affect the methodology. Specifically, expertise in footprint methodologies, MySQL workbench, and MySQL command line will be required. Additionally, depending on the type of data source found, geomatics skills could be required.

Miller, E., Robinson, R., McMaster, M.-L., Holloway, E., and Kapoor, A. (2021). Ontario's Ecological Footprint and Biocapacity: Measures and Trends from 2005 to 2015. Report submitted to the Ontario Ministry of Natural Resources and Forestry.

5. Include other Greenhouse gasses in the National Ecological Footprint and Biocapacity Accounts:

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: Carbon component

Research purpose: expanding the existing framework

Skills needed for research: quantitative skills, EFB methods, MySQL workbench and command line, geomatics

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

The national Ecological Footprint and Biocapacity accounts have been criticized for not including other greenhouse gases (GHG). There is some conceptual discussion on whether this is valid, however, nothing in the framework prevents the inclusion of other GHGs if they were incorporated as CO₂e that could be biologically sequestered. The major limitation to date has been the lack of globally consistent data, especially related to emissions embedded within traded commodities. Partial data could be used to generate estimates that could be included in the more detailed "national workbook" that is already produced for researchers with additional detail beyond the aggregate statistics of Ecological Footprint and Biocapacity, by components.

This will impact all components of the Ecological Footprint to varying degrees for all countries over the full timeline. Additionally, this could potentially affect how the carbon component of the Ecological Footprint is labelled and described. The beginning stages of research require the student to devise the research scope, source new data, and work with spreadsheets and databases. The later stages will require expertise in footprint methodologies to devise how this data will be implemented and the methodology innovated. Additionally, it will

require skills in MySQL workbench, MySQL command line, and potentially in geomatics depending on the data source.

6. Investigating how carbon footprint and ocean sequestration align with other global reporting metrics:

Estimated research time: 6 months

IEFLL research area: metrics and modelling, national applications

Impacts on EFB components: all Ecological Footprint components

Research purpose: increasing applicability of the work

Skills needed for research: quantitative skills, EFB methods knowledge

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Currently, a country's "carbon" footprint component represents a country's demand (on a consumption or production basis) for forested areas to sequester its emissions after deducting the share of emissions that were sequestered by the oceans. As nations are challenged to reduce their emissions and report back to the international community, various approaches have been used to report on emissions and national vulnerabilities. There may be opportunities for greater alignment or production of special equivalents for nations or organizations that find that useful. Some examples of metrics that would be beneficial to align Ecological Footprint and Biocapacity metrics with are Human Appropriation of Net Primary Productivity and/or Planetary Boundaries.

This would impact the carbon component of Ecological Footprint and the forest component of Biocapacity of all countries, to varying degrees on the full timeline. At the beginning stages of the research, the student will devise the research scope, sourcing new data and up-to-date equivalents, and working with spreadsheets and databases. The later stages of research require someone knowledgeable of footprint methodologies to devise alignment and applicability of the metrics.

7. Creating a methodology blueprint of community-specific Ecological Footprint calculators:

Estimated research time: 6-12 months

IEFLL research area: community applications, metrics and modelling

Impacts on EFB components: relating to all Ecological Footprint components

Research purpose: increasing applicability of the work

Skills needed for research: quantitative skills, EFB methods

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Ecological footprint calculators are a valuable tool for people to understand their individual and household impact on the environment and learn ways of transitioning towards a more sustainable lifestyle. Although there are global Ecological Footprint calculators, creating calculators specific for communities allows for more definitive results that can provide more

explicit recommendations for lifestyle changes that global Ecological Footprint calculators cannot always provide. A team of researchers at York University piloted a project creating community-specific Ecological Footprint calculators for parishes in Toronto and the Métis Nation of Ontario. Now that this has proven to be successful, research is needed to synthesize the methodology for creating community-specific footprint calculators. Having a succinct blueprint of the methodology for creating community-specific Ecological Footprint calculators will allow for them to be easily replicated in the future.

This research would be related to all components of Ecological Footprint and Biocapacity, but not directly impact specific components. This research requires someone experienced in working with data and spreadsheets. As the research goes on to devising the blueprint of the methodology, it will require someone to be deeply knowledgeable about footprint methodologies.

8. Generating Ecological Footprint metrics that align with the System of Environmental and Economic Accounting (SEEA):

Estimated research time: 1-2 years

IEFLL research area: metrics and modelling, national applications

Impacts on EFB components: relating to all Ecological Footprint and Biocapacity components

Research purpose: increasing applicability of the work

Skills needed for research: quantitative skills, knowledgeable about SEEA, SNA, and EFB methods

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

The SEEA is a framework synthesizing economic and environmental data and providing an exhaustive picture of the interconnections between the environment and the economy, including the stocks and changes in stocks. The framework includes internationally agreed-upon standard concepts, definitions, accounting rules, and classifications, for producing internationally comparable statistics and accounts. These conform and are consistent with the System of National Accounts. Currently, the national Ecological Footprint and Biocapacity accounts do not have metrics that align with the SEEA, or the SNA. Innovating on Ecological Footprint and Biocapacity methodologies to align with the SEEA would enhance the legitimacy and applicability of footprint methodologies.

This research relates to all components of Ecological Footprint and Biocapacity and could impact all the components to varying degrees depending on how much reconciliation with the SEEA is done. Additionally, this research will enhance the number of ways that Ecological Footprint and Biocapacity data can be used by other organizations. The beginning stages of the research require the student to devise the research scope, source new data and up-to-date equivalents, work with spreadsheets and databases, and understand the SEEA and SNA. The later stages of research require someone knowledgeable of footprint methodologies to devise the metrics that align with the SEEA.

9. What is the relationship between biodiversity and Biocapacity? Can Biocapacity be used to measure the impacts on Biodiversity?

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to all Biocapacity components

Research purpose: increasing applicability of the work

Skills needed for research: ecology/biology knowledge, quantitative skills, GIS

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

Biocapacity measures the regenerative capacity of lands and waters and their capacity to absorb waste generated by humans. This is not a direct measurement of biodiversity, although it relates to the productivity of ecosystems. The Kunming-Montreal Biodiversity Framework has multiple mentions of Ecological Footprint in the measurement section. Additionally, the Ontario Biodiversity Council uses Ecological Footprint and Biocapacity metrics as key metrics to inform human pressures on biodiversity. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) also uses Ecological Footprint and Biocapacity data to identify reasons why people should be interested and concerned for ecosystem services and biodiversity. Although several biodiversity initiatives use Ecological Footprint and Biocapacity data, there is limited literature that characterizes the relationship between Biocapacity and biodiversity. Additionally, this could lead to improvements in Biocapacity methodology.

The beginning stages of research require the student to devise the research scope, source data, and literature on biodiversity, Biocapacity, and potentially other sustainability metrics and standards. Additionally, it will require the student to be knowledgeable about ecology and biodiversity. Moreover, the student should have quantitative skills to be able to work with Biocapacity and biodiversity data. Potentially the student could have to work with geographic data.

10. What is the capacity of intensively managed ecosystems to provide specific goods and services?

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to cropland, fishing grounds, grazing land, and forest land components of Biocapacity

Research purpose: refining the existing framework

Skills needed for research: quantitative skills, EFB methods, potentially GIS

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

The concept of Biocapacity is founded on the principle that natural ecosystems have a finite capacity to supply various goods and services. However, through human interventions

(e.g. agricultural practices), the natural capacity to produce agricultural goods has increased manyfold. Intensive management requires inputs of labour, materials, and energy. If abundant supplies of these inputs are available, what is the Biocapacity of a given ecosystem to supply desired goods and services? This research should culminate in a “manual” for forecasting the Biocapacity of intensively managed ecosystems. Pragmatically, the manual should focus on a specific set of goods and services associated with a specific type of intensively managed ecosystem.

To be Explored Research Questions:

1. How can the built-up land component be adapted to account for the multiple ecosystem services provided by urban green spaces within built-up land?

Estimated research time: 6-12 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to the built-up land component

Research purpose: refining the existing framework

Skills needed for research: EFB methods knowledge, quantitative skills, MySQL workbench and command line, urban planning knowledge, GIS skills

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

2. How well do equivalence factors apply across multiple scales, and time, when comparing Biocapacity between regions and countries?

Estimated research time: 6 months

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to all Biocapacity components

Research purpose: refining the existing framework

Skills needed for research: EFB methods knowledge, quantitative skills, MySQL workbench and command line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

3. What are the most effective spatial analysis techniques for examining land-use change and ownership? How do different types of land use and land ownership affect the Ecological Footprint and Biocapacity ratio among countries?

Estimated research time: 6 months

IEFLL research area: responsive scaling, community applications

Impacts on EFB components: relating to all components of Ecological Footprint and Biocapacity

Research purpose: expanding the existing framework

Skills needed for research: GIS and geomatics skills, urban planning knowledge, equity and justice knowledge, quantitative skills

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

4. How can the inclusion of stocks in Ecological Footprint and Biocapacity accounting improve the methodology? Will this improve the comparability of the results between different countries and regions?

Estimated research time: 1-2 years

IEFLL research area: national applications, responsive scaling

Impacts on EFB components: relating to all components of Ecological Footprint and Biocapacity

Research purpose: expanding the existing framework

Skills needed for research: quantitative skills, EFB methods knowledge, MySQL workbench and command-line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

5. What are the most effective methods for localized data gathering and reconciliation with regional data, to support the use of the Ecological Footprint and Biocapacity in municipal and sub-national planning and policy development?

Estimated research time: 6-12 months

IEFLL research area: responsive scaling, national applications

Impacts on EFB components: relating to all components of Ecological Footprint and Biocapacity

Research purpose: increasing the applicability

Skills needed for research: qualitative and quantitative skills, EFB methods, and urban planning knowledge

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

6. In what ways can the narrative of Ecological Footprint and Biocapacity, particularly the National Accounts, be reframed to increase engagement and understanding?

Estimated research time: 6 months

IEFLL research area: National applications, community applications

Impacts on EFB components: relating to all components of Ecological Footprint and Biocapacity

Research purpose: increasing the applicability

Skills needed for research: qualitative skills, communications and media skills

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

7. What is the proportion of the Ecological Footprint of Consumption by tourists compared to residents in countries that have high tourism levels?

Estimated research time: 6-12 months

IEFLL research area: responsive scaling, national applications

Impacts on EFB components: relating to all components of Ecological Footprint (of Consumption)

Research purpose: expanding the existing framework

Skills needed for research: quantitative skills, EFB methods knowledge, MySQL workbench and command-line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

8. Creation of a database of embodied Ecological Footprint for man-made materials

Estimated research time: 1-2 years

IEFLL research area: metrics and models, responsive scaling

Impacts on EFB components: relating to all components of the Ecological Footprint

Research purpose: increasing the applicability

Skills needed for research: quantitative and coding skills, EFB methods knowledge, MySQL workbench and command-line

IEFLL Partner(s) involved: TBD

Researcher(s): TBD

9. Deriving a nutrition index for other commodities, beyond cereals, for the cropland component of Ecological Footprint

Estimated research time: 6-12 months

IEFLL research area: national applications

Impacts on EFB components: relating to the cropland component of Ecological Footprint

Research purpose: refining the existing framework

Skills needed for research: quantitative skills, EFB methods knowledge, MySQL workbench and command-line, food and nutritional sciences knowledge

IEFLL Partner(s) involved: TBD

Researcher(s): TBD