RES 500E Exploring the food-energy-water nexus 2019W T1

Course Syllabus

Instructor: Dr. Mark S. Johnson <mark.johnson@ubc.ca>
Class time: Tuesdays 2:00 to 5:00 (2202 Main Mall, AERL building, Room 107)

DESCRIPTION

Feeding one billion people requires the annual provision of one quadrillion (10^15) calories (kcal). Because plants use an average of 1 L of water during crop growth for each calorie of food energy produced, the projected growth in the global population from today's 7.5 billion to 9.5 billion in 2050 will increase agriculture's portion of the water footprint of humanity by two quadrillion L – or more, since meat has a water footprint 20X greater than cereal grains. These changes will greatly increase agriculture's impacts on the water cycle, deepening its effects on surface water flows, water pollution and groundwater levels. Global food security is thus intimately tied to freshwater availability, with increasing challenges due to declining water tables and issues related to water quality and changing precipitation patterns. Coupled to that are energy considerations – energy required to produce fertilizers, operate farm equipment, process and distribute food, as well as food used as energy (i.e. biofuels). In this graduate seminar course, students will explore these and other dimensions of the food-energy-water nexus.

FORMAT

The course follows a seminar format, and meets once a week for 3 hours. Each class meeting will consist of an informal lecture and a student-led discussion session. Assigned readings will be discussed and further explored through in-class exercises and assignments that reinforce the topic.

EVALUATION

- 25% Facilitation
- 15% Case study / method / model / tool summary
- 30% Project paper
- 15% Project presentation
- 15% Participation

FACILITATION

Student facilitation is a key component of this course as it allows students to take greater ownership over the course, provides opportunities to enhance learning and hopefully pushes everyone a bit outside of their comfort zones. For this course, facilitation involves conducting a focused review of the topic, providing a synthesis of the range of approaches that have been (or could be) brought to bear. You should explore the literature on the topic from several disciplinary perspectives, indicating advances, uncertainties, and future research directions on the topic, and suggest any key references that we should add to a supplemental course reading list (no more than 3-5 suggestions please). This information will be conveyed to the class as a facilitated discussion, and should include audio-visual materials presented in an engaging manner. Clips from archived conference presentations and/or webinars are also appropriate.

The facilitator will also provide a summary of key findings from the week's readings, which can include a look forward and back at citations (e.g. check out which papers cite the readings, and which papers the readings cite). Other students will provide 2-3 discussion questions each, which the facilitator can incorporate in the discussion of the readings. Discussion questions should be emailed to the facilitator (with a copy to the course instructor) well in advance of class (e.g. by noon on Mondays).

Facilitation Guide

- Identify 2-3 key papers for topic
  - Confirm suggestions with professor one week prior to facilitated session
- Collect discussion questions from classmates
  - Class to email questions to facilitator no later than Mondays at noon
  - Review and select a few (3-5) questions for in class discussion
- Prepare brief presentation materials summarizing topic:
  - context, state-of-the-art, methodologies used, and key applications
- Prepare paper summaries
  - Why is this paper significant?
    - What is its primary contribution?
    - What has it influenced?
  - Include notes on paper's authors to inform context
- Guide discussion using submitted questions as points of entry
  - Identify key points/take-aways

Exploring the FEW Nexus: Case study / method / model / tool summary

Each student will present a summary that helps to explore the food-energy-water nexus via a case study or summary of a method, model, or tool that can be used to analyze or evaluate the nexus. For case study summaries, in-class presentations (10 – 12 minutes) will provide the background context of the case, and explore drivers and linkages between the system or case of interest. A list of potential cases is available at the end of the syllabus. Methodological presentations (also 10 – 12 minutes) will discuss the assumptions and objectives of the technique, examples where it has been used, and any known limitations. A list papers reviewing methodological approaches is available at the end of the syllabus. Students can choose to present on either a case study or a methodological approach. Regardless, students should discuss their choice of method with the instructor during the week prior to their presentation.

TERM PROJECT

Term projects provide an opportunity to explore a topic/case/theme of the course in more depth. Students may wish to (i) apply a model or other analysis to a specific case, (ii) design a survey to evaluate decision making process related to food-energy-water nexus, (iii) prepare a policy brief on a topic germane to the FEW nexus. Feel free to get creative, and students are welcome to suggest projects from different modalities to those listed above. All projects will have a written component (approximately 10-12 double spaced pages not including tables or figures, 12 point font, 1 inch margins), and will be presented to the class during the last class session(s). For example, if you wish to prepare a policy brief (which would only span a couple of pages), additional background information can be provided as extended footnotes and an annotated bibliography to the project.

Key dates for the term project: (see next page)

Key dates for the term project:

Sept 24: Discuss ideas with instructor

- Email project proposal brief to professor

Oct 8: "Pitch" your idea to class

- Discuss objectives, scope, approach, and related details

Nov 19 and 26: Present findings

- 10-12 minute presentation followed by Q&A

Dec 3: Submit write up

- Email project paper to instructor. Paper length described above.

PARTICIPATION

As a graduate seminar, being physically and intellectually present during class is expected of all course members. We are hoping to create a participatory environment where we can both gain knowledge and question assumptions, which requires engagement from all. Hands-on participation is guaranteed through the facilitation roles each will play, as well as through preparation of discussion questions based on the week's readings.

READINGS

[NOTE – *readings will be revised based on discussions between instructor and student facilitator*]

September 10

- Papers for discussion on **Exploring FEW Nexus concept**
    - Interview at https://eos.org/editors-vox/the-challenges-of-meeting-future-food-energy-and-water-needs
    - D'Odorico, P., K. F. Davis, L. Rosa, J. A. Carr, D. Chiarelli, J. Dell'Angelo, J. Gephart, G. K. MacDonald, D. A. Seekell, S. Suweis, and M. C. Rulli (2018), The Global Food-Energy-Water Nexus, *Rev. Geophys., 0(0)*, doi:10.1029/2017RG000591.
        - *Read through end of pg 21* – we will revisit the rest of this paper in later weeks
    - Jones, K. et al. (2017), An Overview of Conceptual Frameworks, Analytical Approaches and Research Questions in the Food-Energy-Water Nexus, *SESYNC White Paper*.
    - The World Economic Forum Water Initiative (2011), The Water-Food-Energy-Climate Nexus: A Facts and Figures Overview, in *Water Security: The Water-Food-Energy-Climate Nexus*, Island Press/Center for Resource Economics, Washington, DC, pp. 1-16, doi:10.5822/978-1-61091-026-2_0.
    - Critiques of the concept:
        - http://dx.doi.org.ezproxy.library.ubc.ca/10.1038/538140b
        - Wichelns, D. (2017), The water-energy-food nexus: Is the increasing attention warranted, from either a research or policy perspective?, *Environ. Sci. Policy, 69*, 113-123, doi:10.1016/j.envsci.2016.12.018.

September 17

- Papers for discussion on **Water use in agriculture**
    - Grafton R.Q et al. (2018). The paradox of irrigation efficiency. *Science*, *361*(6404), 748-750.
    - Mekonnen, M. M., & Hoekstra, A. Y. (2011). The green, blue and grey water footprint of crops and derived crop products. *Hydrology and Earth System Sciences*, *15*(5), 1577-1600.
    - **Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan, and Colombo: International Water Management Institute. **Summary only

- Porkka, M., Gerten, D., Schaphoff, S., Siebert, S., & Kummu, M. (2016). Causes and trends of water scarcity in food production. *Environmental Research Letters*, *11*(1), 015001.

September 24

- Papers for discussion on **Virtual water trade network**
  - Allan, J. A. (1998). Virtual water: A strategic resource. *Ground Water*, 36(4), 545-546.
  - Allan, J. A. (2013). Food-Water Security: Beyond Water Resources and the Water Sector. In Lankford, Bruce, et al. Water Security : Principles, Perspectives and Practices, Routledge, 2013.
  - Dalin, C., Konar, M., Hanasaki, N., Rinaldo, A., & Rodriguez-Iturbe, I. (2012). Evolution of the global virtual water trade network. *Proceedings of the National Academy of Sciences of the United States of America*, 109(16), 5989-5994.
  - Wichelns, D. (2015). Virtual Water and Water Footprints: Overreaching Into the Discourse on Sustainability, Efficiency, and Equity. *Water Alternatives*, 8(3).

October 1

- Papers for discussion on **Virtual water trade network**
  - Liu, Y., M. Hejazi, P. Kyle, S. Kim, E. Davies, D. Gonzalez Miralles, A. J. Teuling, Y. He, and D. Niyogi. "Global and Regional Evaluation of Energy for Water." *Environmental Science and Technology* 50, no. 17 (2016)
  - Copeland, Claudia, and Nicole Carter. "Energy-Water Nexus: The Water Sector's Energy Use." Congressional Research Service Report. (2017) http://www.ourenergypolicy.org/wp-content/uploads/2017/02/R43200.pdf
  - Smith, Kate, Shuming Liu, Yi Liu, Ying Liu, and Tao Wang. "City Layout: A Key to Reducing Energy use for Water Supply." *Resources, Conservation & Recycling* 138, (2018): 229-230.
  - Optional paper for those interested:
    - Voutchkov, Nikolay. "Energy use for Membrane Seawater Desalination – Current Status and Trends." Desalination 431, (2018): 2-14.

October 8

- Papers for discussion on **Water in energy generation**
  - Macknick et al. (2012), Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature, *Environ. Res. Lett., 7(4)*, 045802.
  - Spang et al. (2014), The water consumption of energy production: an international comparison, *Environ. Res. Lett., 9(10)*, 105002.
  - Cornwall, W. (2016), Hundreds of new dams could mean trouble for our climate, *Science*, doi:10.1126/science.aah7356.

October 15

- Papers for discussion on **Energy use in agriculture**
  - Ali et al. (2019), Impact assessment of energy utilization in agriculture for India and Pakistan, *Sci. Total Environ., 648*, 1520-1526.
  - Pimentel, D., M. Pimentel, and M. Karpenstein-Machan (1999), Energy use in agriculture: An overview, *Agricultural Engineering International: CIGR Journal*.
  - Pimentel, D. (2006), Impacts of organic farming on the efficiency of energy use in agriculture, An Organic Center State of Science Review.

October 22

- Papers for discussion on **Bioenergy**
    - Rulli et al. (2016), The water-land-food nexus of first-generation biofuels, *Scientific Reports,* 6:22521.
    - Searchinger et al. (2008), Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change, *Science* 319: 1238-1240.
    - Fargione et al. (2008), Land clearing and the biofuel carbon debt, *Science* 319:1235-38.
    - Hill et al. (2006), Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels, *Proceedings of the National Academy of Sciences* 103:11206-10.
    - Optional paper of interest:
        - Rodriguez et al. (2018), Biofuel-water-land nexus in the last agricultural frontier region of the Brazilian Cerrado, *Appl. Energy*.
        - Edenhofer et al. (2011), *Renewable energy sources and climate change mitigation: Special report of the Intergovernmental Panel on Climate Change*, Cambridge University Press.

October 29

- Papers for discussion on **Urban metabolism**
    - Kennedy, C., J. Cuddihy, and J. Engel-Yan (2008), The Changing Metabolism of Cities, *J. Ind. Ecol., 11(2)*, 43-59, doi:10.1162/jie.2007.1107.
    - Villarroel Walker, R., M. B. Beck, J. W. Hall, R. J. Dawson, and O. Heidrich (2014), The energy-water-food nexus: Strategic analysis of technologies for transforming the urban metabolism, *J. Environ. Manage., 141*, 104-115, doi:10.1016/j.jenvman.2014.01.054.
    - Wolman, A. (1965), The metabolism of cities, *Sci. Am., 213(3)*, 178-193. https://www.jstor.org/stable/pdf/24931120.pdf

November 5

- Papers for discussion on **SDGs and the FEW Nexus**
    - Biggs et al. (2015), Sustainable development and the water–energy–food nexus: A perspective on livelihoods, *Environ. Sci. Policy, 54*, 389-397, doi:10.1016/j.envsci.2015.08.002.
    - Fuso Nerini et al. (2018), Mapping synergies and trade-offs between energy and the Sustainable Development Goals, *Nature Energy, 3(1)*, 10-15, doi:10.1038/s41560-017-0036-5.
    - Stephan et al. (2018), Water–energy–food nexus: a platform for implementing the Sustainable Development Goals, *Water Int., 43(3)*, 472-479, doi:10.1080/02508060.2018.1446581.
    - Weitz et al. (2014), Cross-sectoral integration in the Sustainable Development Goals: a nexus approach, Stockholm Environment Institute: Stockholm, Sweden. https://www.sei.org/mediamanager/documents/Publications/Air-land-water-resources/SEI-DB-2014-Nexus-SDGs-integration.pdf

November 12

- Papers for discussion on **Sustainability of FEW Nexus**
    - Conrad, S.A., 2012. Decision support for the water-energy nexus: Examining decision-making in the American West, in: Kenney, D.S. (Ed.), The Water Energy Nexus in the American West. pp. 192–209.

- (skim) Lam, K.L., Lant, P.A., O'Brien, K.R., Kenway, S.J., 2016. Comparison of water-energy trajectories of two major regions experiencing water shortage. Journal of Environmental Management 181, 403–412. doi:10.1016/j.jenvman.2016.06.068
- (skim) Stokes, J.R., Horvath, A., 2009. Energy and Air Emission Effects of Water Supply. Environmental Science & Technology 43, 2680–2687. doi:10.1021/es801802h

November 19 and 26: Term project presentations

Case Studies (possible selections for the case study presentations)

- Seven cases are in Flammini, A., M. Puri, L. Pluschke, and O. Dubois (2014), Walking the nexus talk: assessing the water-energy-food nexus in the context of the sustainable energy for all initiative, FAO. Available online at http://www.fao.org/3/a-i3959e.pdf
- Numerous case studies outlined by CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at https://csa.guide/#chapter-case-studies

Web-based models/tools for evaluating the FEW nexus (not a complete list)

- The Water Risk Filter http://waterriskfilter.panda.org/
- Water Analysis Tool for Energy Resources (WATER) http://water.es.anl.gov/
- WESTWeb Water Energy Sustainability Tool http://west.berkeley.edu/model.php
- WEFNexusTool http://wefnexustool.org/ (seems limited to Qatar at present)
- UN Water-Energy Nexus Operational Toolkit: Resource Efficiency Module https://www.water-energy-food.org/resources/tools-and-databases/ [multiple tools described here]
- Nexus Tools Platform - an interactive platform for inter-model comparison of existing modelling tools [UN University] http://ntptools.ara.uberspace.de/en/

Papers focusing on methods/models/tools for evaluating the FEW nexus

Al-Saidi, M., and N. A. Elagib (2017), Towards understanding the integrative approach of the water, energy and food nexus, *Sci. Total Environ., 574*, 1131-1139, doi:10.1016/j.scitotenv.2016.09.046.

Albrecht, T. R., A. Crootof, and C. A. Scott (2018), The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment, *Environ. Res. Lett., 13(4)*, 043002, doi:10.1088/1748-9326/aaa9c6.

Dai, J., S. Wu, G. Han, J. Weinberg, X. Xie, X. Wu, X. Song, B. Jia, W. Xue, and Q. Yang (2018), Water-energy nexus: A review of methods and tools for macro-assessment, *Appl. Energy, 210*, 393-408, doi:10.1016/j.apenergy.2017.08.243.

Hussien, W. e. A., F. A. Memon, and D. A. Savic (2017), An integrated model to evaluate water-energy-food nexus at a household scale, *Environmental Modelling & Software, 93*, 366-380, doi:10.1016/j.envsoft.2017.03.034.

Jones, K., N. R. Magliocca, and K. Hondula (2017), An Overview of Conceptual Frameworks, Analytical Approaches and Research Questions in the Food-Energy-Water Nexus, *SESYNC White Paper*.

Kaddoura, S., and S. El Khatib (2017), Review of water-energy-food Nexus tools to improve the Nexus modelling approach for integrated policy making, *Environ. Sci. Policy, 77*, 114-121, doi:10.1016/j.envsci.2017.07.007.

Karabulut, A. A., E. Crenna, S. Sala, and A. Udias (2018), A proposal for integration of the ecosystem-water-food-land-energy (EWFLE) nexus concept into life cycle assessment: A synthesis matrix system for food security, *J. Cleaner Prod., 172*, 3874-3889, doi:10.1016/j.jclepro.2017.05.092.

Kling, C. L., R. W. Arritt, G. Calhoun, and D. A. Keiser (2017), Integrated Assessment Models of the Food, Energy, and Water Nexus: A Review and an Outline of Research Needs, *Annual Review of Resource Economics, 9(1)*, 143-163, doi:10.1146/annurev-resource-100516-033533.

Mannan, M., T. Al-Ansari, H. R. Mackey, and S. G. Al-Ghamdi (2018), Quantifying the energy, water and food nexus: A review of the latest developments based on life-cycle assessment, *J. Cleaner Prod., 193*, 300-314, doi:10.1016/j.jclepro.2018.05.050.

Martinez-Hernandez, E., M. Leach, and A. Yang (2017), Understanding water-energy-food and ecosystem interactions using the nexus simulation tool NexSym, *Appl. Energy, 206*, 1009-1021, doi:10.1016/j.apenergy.2017.09.022.

Owen, A., K. Scott, and J. Barrett (2018), Identifying critical supply chains and final products: An input-output approach to exploring the energy-water-food nexus, *Appl. Energy, 210*, 632-642, doi:10.1016/j.apenergy.2017.09.069.

Shannak, S. d., D. Mabrey, and M. Vittorio (2018), Moving from theory to practice in the water–energy–food nexus: An evaluation of existing models and frameworks, *Water-Energy Nexus, 1(1)*, 17-25, doi:10.1016/j.wen.2018.04.001.

Zhang, C., X. Chen, Y. Li, W. Ding, and G. Fu (2018), Water-energy-food nexus: Concepts, questions and methodologies, *J. Cleaner Prod., 195*, 625-639, doi:10.1016/j.jclepro.2018.05.194.