Comprehensive Portfolio

IPSITA KUMAR

Department of Geographical Sciences,

University of Maryland

Portfolio Advisory Committee

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Table of Contents

1. Curriculum Vitae

Ipsita Kumar

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EDUCATION

PhD Candidate, University of Maryland, College Park 2018 - Present
M. A. Climate & Society, Columbia University in the City of New York 2013- 2014
M. Sc. Economics (Environment & Resources) TERI University, Delhi 2009-2011
B. A. Economics Honors, Lady Shri Ram College, Delhi University 2006-2009

RELEVANT EXPERIENCE

University of Maryland, College Park Aug, 2018 – Present
Teaching Assistant (TA)

- TA for course "Developing Countries" in Fall, 2018
- TA for course "Introduction to Human Geography" in Spring, 2019

Center for Social Science and Humanities, Delhi May 2018 – July, 2018
Part time Research Assistant

- Working on estimating feed availability for livestock in India
    - Compiling data for estimating the availability feed in the past
    - Developing a model to estimate the availability in the past and present

Columbia Water Centre, Columbia University, New York Feb 2015 – Mar 2018
Staff Associate

- Reservoir Optimization Model for Pernambuco, Brazil: Developed a model to minimize cost of water delivery through reservoir optimization models for the state of Pernambuco, targeting major reservoirs in the state. Using Nonhomogeneous Hidden Markov Models to make rainfall forecasts to use in the reservoir optimization model.
    - Developed an user interface for the optimization model, available at https://columbia-water-center.shinyapps.io/hydrobid_opt_reservoir_optimization/

Columbia University, New York Dec 2014 – Feb 2015
Volunteer – Editorial Assistant, Prof. John C. Mutter (Department of Earth and Environmental Sciences; International Public Affairs)

- Editorial Assistant to Prof. Mutter on his book "Disaster Profiteers: How Natural Disasters Make the Rich Richer and the Poor Even Poorer" (St. Martin's Press).

University of West Indies, Jamaica/Columbia University June 2014 – July 2014
Intern

- Worked on a research with University of Arizona, Government of Jamaica and the University of Uruguay on climate services and needs of different stakeholders, focusing on agriculture.

NASA Goddard Institute for Space Studies Sep 2013 – June 2014
Research Assistant, Urban Climate Change Risk Assessment

- Conducted a survey for impact assessment of the First Assessment Report of the Urban Climate Change Research Network (ARC3)

Columbia University, New York Dec 2013 – June 2014
Research Assistant, Prof. John C. Mutter

- Performed regression analysis for a link between Disasters and Development.
- Addressed socio-economic aspects of Disasters and Development

The Energy and Resources Institute (TERI), Delhi June 2011 – Aug 2013
Research Associate

- Principal Investigator
  TERI Environmental Survey: Survey to assess perception, behaviour, attitude, etc. of people towards the environment in 6 Indian cities with a sample of over 4000.
  Sustainable Development Goals (SDGs): Researched and conducted stakeholder dialogue for optional design and framework for SDGs.
- Other Select Research
  BIOCORE Research for the European Union: Studied the social, political and legal aspects of 2nd generation bio-refineries in France, Germany, Hungary and India.
  Organic Agriculture: Analysed pathways for sustainability of organic agriculture.
  Resource Efficiency in India: Handled research on middle class consumption, Indian policies related to resource efficiency (in particular minerals).

United Nations Development Programme, Delhi Jan 2011 – June 2011
Internship/Master's Thesis

Conducted research on the topic Gender and Climate Change, in particular the link between gender and climate change in India

PUBLICATIONS (PEER REVIEWED)

White, I, Lawless, KL, Vivoni, ER, Nascaro, G, Pahle, R, **Kumar, I,** Coli, P, Castillo, RM, Moreda, F, Asfora, M (2018) *Co-Producing Interdisciplinary Knowledge and Action for Sustainable Water Governance: Lessons from the Development of a Water Resources Decision Support System in Pernambuco, Brazil*. Global Challenges. DOI: 10.1002/gch2.201800012

OTHER PUBLICATIONS

Kumar, I, Zhu, S (2015) *Water Management and Climate Change — The Case for Newark and Philadelphia*. Columbia Water Center White Paper. Available at: http://water.columbia.edu/files/2015/10/White-paper-Ipsita-Kumar-Siquan-Zhu-FINAL-22-Oct.pdf

Gannon, C, Kandy, D, Turner, J, **Kumar, I,** Pilli-Sihvola, K, Chanda, F S (2014) *Near-term climate change in Zambia. What the research tells us*. Red Cross/Red Crescent Climate Centre, Hague.

Kapur, S. K., **Kumar, I.**, (2013) India and Sustainable Development Goals (SDGs). TERI Policy Brief Issue 10 November 2013. *New Delhi.*

IFEU-Institut et. al., TERI, GIZ (2013), *India's Future Needs for Resources, Dimensions, Challenges and Possible Solutions*. TERI, GIZ, IFEU *Heidelberg, Delhi* **(Consortium Member)**

Piotrowski, S, Carus, M, Sibilla, F, Beckmann, J, Kapur, S, Bhattacharjya, S, Kumar I, Diaz-Chavez, R, (2013) *Final assessment of the economic, social/legal/political sustainability of the BIOCORE biorefining system*. European Union 7th Framework Programme (FP7) BIOCORE Project Report.

CONFERENCE PRESENTATIONS

Kumar I, Josset, L, Silva, EC, Possas, JMC, Asfora, MC, Lall, U (2017) *Financial Risk Reduction and Management of Water Reservoirs Using Forecasts: A Case for Pernambuco, Brazil*. Abstract [Number: H11J-1340] presented at 2017 Fall Meeting, AGU, New Orleans, L.A., 11-15 Dec.

Kumar, I, Josset, L, Lall, U, Silva, EC, Possas, JMC, Asfora MC (2017) *Cost Optimization of Water Resources in Pernambuco, Brazil: Valuing Future Infrastructure and Climate Forecasts*. Geophysical Research Abstracts Vol. 19, EGU2017-10147, 2017. EGU General Assembly 2017, Vienna, Austria.

WORKING PAPERS

"Forecast based reservoir system operation as a climate change adaptation strategy" (with Josset, L, Silva, EC, Possas, JMC, Asfora, MC, Lall, U)

OTHERS

- Awarded Deans Fellowship from University of Maryland (2018-2019)
- Awarded $30,000 scholarship from the Department of Earth and Environmental Sciences, Columbia University for MA Climate and Society (2013-2014)

SKILLS

Programming Skills – R, R Shiny, Matlab | Languages: English, Hindi, Nepali

2. Goal Description

2.1. Original Goal Statement

Securing a safe and reliable water supply is crucial for thriving communities and ecosystems. Yet, this task is becoming increasingly challenging given shifting demands and water availability, which are driven by increased populations, changes in climate, and evolving preferences, production and distribution of food, energy and manufactured goods. Limitations and uncertainty in water supply have contributed to increased competition between the food and energy sectors. This competition is becoming increasingly common around the world and affecting economic growth, policy, and society. To achieve an equitable and efficient food-energy-water (FEW) nexus, improved understanding of linkages and feedback are needed in order to (i) reduce future uncertainties in climate forecast and resource availability; (ii) reduce cost of supply for efficient allocation of resources; (iii) improve infrastructural planning; and (iv) inform adaptation policies.

My particular interest in the FEW nexus is in identifying strategies to provide solutions for water supply, demand, and infrastructure challenges that will be critical to ensure food and energy security into the future. Through an interdisciplinary research approach, I aim to advance the science of this nexus by improving and developing innovative methods for forecasting climate and modeling hydrologic and economic systems.

My interest in the broad field of environmental and resource economics was fostered during an internship with UNWomen in 2007 that focused on gender and energy access and the realization that primary resources such as energy, clean water, and food were critical to survival, productivity, and equality. My academic interests have since evolved to a more interdisciplinary approach focusing on water management and planning through understanding water supply and demand and how both endogenous and exogenous factors may impact water resources (e.g. climate variability, demographic shifts and infrastructural development).

I obtained a B.A. (Honors) in Economics (2009) from Lady Shri Ram College, Delhi University, followed by an M.Sc. in Economics (2011) from TERI University, and an M.A. in Climate and Society (2014) from Columbia University. My M.Sc. Economics provided me with a foundation in core economics theories, along with a specialization in environment and resource economics. My M.A. Climate and Society served to further my knowledge of climate science and understanding its use in economic research. It allowed me to develop theoretical approaches to climate dynamics and science, along with understanding its impact on socio-economic growth.

In addition to my academic endeavors, I worked as a Research Associate at The Energy and Resources Institute (June 2011 to August 2013). I conducted research on sustainability of organic agriculture in the rain-fed mountainous region of Uttarakhand, India; clean energy technology for employment generation, targeting women's self-help group, and; metals and minerals efficiency, targeting key users, including the building and automotive industry. During my M.A. in Climate and Society, I worked on three research projects focusing on:

the effects of natural disasters on social and economic development with Prof. John Mutter; urban climate change risk with NASA Goddard Institute for Space Studies; and the use of rainfall and temperature forecast to make farming decisions at the University of West Indies, Jamaica.

Since February, 2015, I have been working at the Columbia Water Center (CWC) with a focus on water supply and infrastructure. During my first six months, I conducted research to understand vulnerabilities associated with water supply in Philadelphia under different climate scenarios. In my current research, funded by the Inter-American Development Bank, I developed two models to apply in the case of Pernambuco, Brazil. The aim of the study was to use forecasts as a basis for climate adaptation strategy in order to improve water management, in particular reducing supply cost while ensuring demand reliability. The first model developed provides daily rainfall forecasts at a seasonal time scale for point locations. These results were then used to produce streamflow forecasts. The second model used the streamflow forecasts as an input into a linear optimization model to reduce both, the water supply costs from reservoirs and import sources and a cost of deficit (i.e. failure to provide water).

Through my academic and research experiences I have developed the skills required to conduct research in an independent manner in addition to working efficiently, constructively, and productively within teams of various sizes. I am experienced in conducting both office and field-based research. Through my office-based research, I have gained experience in using R to process large data sets, develop models, produced graphical displays, and analyze data. I also have experience in R shiny, which I am using to create interfaces for the two models developed at CWC. Through my field-based research, I developed critical skills in conducting face-to-face interviews, facilitating stakeholder discussion and dialogue, focus group discussions, and leading multi-stakeholder training and other workshops. I communicated my research outcomes through presentations at international conferences and workshops with key stakeholders. I have organized events including international conferences, press releases and other smaller stakeholder conferences. I also taught research techniques and courses to mid-career professionals. Finally, I have written proposals and successfully received funds from organizations like DFID, World Bank, etc.

Obtaining a PhD is a natural next step for me given my past experiences and future goals in research and academia. I aim to continue working on issues related to the FEW nexus, with a focus on water supply and demand. I believe the Department of Geographical Sciences at the University of Maryland will provide me with excellent opportunities to pursue my goals and to contribute to the direction of the department. To achieve an interdisciplinary approach to my research, I am seeking flexibility in courses and access to faculty in a range other disciplines (e.g. Business, Economics, Hydrology and Climate Science), which is available in this program. The Department of Geographical Sciences has produced a large body of high quality research and its faculty and staff are working on issues that are well aligned with my interests. Finally, the research at the Department, with its interdisciplinary

approach to problem solving, along with an excellent faculty, research and student group, would benefit me immensely and I could also bring my knowledge, skills and expertise to help develop the team.

I would like to work with Prof. Klaus Hubacek, as his work on modeling, resource management, in particular, his work on the food-energy-water nexus is fundamental for my research. His work on the interaction between social science and science is very similar to my future interest at the Department. I want to collaborate with Prof. Fernando Miralles-Wilhelm for his work on hydrology, which is an important part of water research. He has been working on application based research, by bringing the societal element to water management, which is in line with what I want to do. Finally, I am interested in working with Prof. Laixiang Sun on his work on risk reduction and climate adaptation. In particular, his work on risk reduction and natural adaptation on soybean production is relevant.

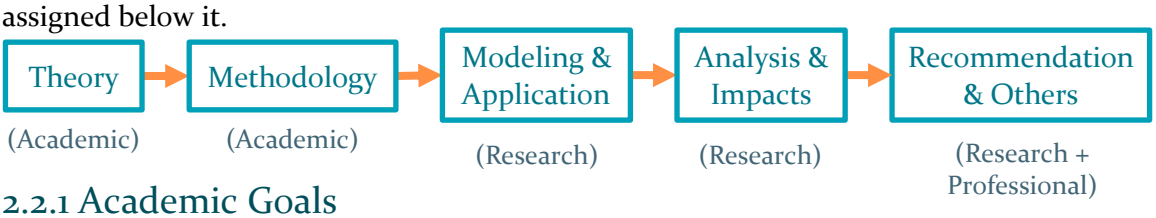
In conclusion, I am excited about an opportunity to do a PhD in Geographical Sciences at the University of Maryland, and I thank you for your time spent in reviewing my application.

2.2. Current Goal Statement

I am interested in working in the food-energy-water nexus, with a focus on water management. Water management has always been a cause of concern, especially in areas which have been historically susceptible to droughts, or whose economy and/or population heavily relies on agriculture, mining, etc. However, with changes in climate, consumption, population, urbanization, etc., this is becoming an even more important topic to study as more regions, economies, societies, industries, etc. are feeling the effects of water deficit than ever before. Water management has always been in interdisciplinary field, as infrastructure, climate modeling, economics, social sciences, earth sciences, governance, policy, and many other fields coming into play. Therefore, developing interdisciplinary models and methods is this topic is a necessity.

My overall goal is to become a professor at a university or a research scientist at a university or a research institution. To achieve my overall goal, my academic, research and professional goals are complementary of one another. I have always wanted to stay in the field of research, for which, pursuing a PhD was a natural next step. Pursuing my PhD will help me achieve my goals by providing me with an opportunity to grow as a researcher, as well as help me develop comprehensive techniques to conduct research and to be able to use that research for improved policy, planning and practice. During my PhD, I hope to use my past experience in water management, modeling and interdisciplinary research to further improve models and methods available for water management. With my PhD, I hope to continue working in the same field, but as a stronger scientist, with improved understanding of the field of water management and with the tools necessary to do great research. I feel that while it is important to stay rooted in academia, it is also critical to be able to develop research and professional skills, which could be used to better help policy, decision-making and practice. Given the overlap in my overall goals and intentions of becoming a researcher, I have put the three goals into broad categories of research, as seen

in the chart below. While there are overlaps, a large portion of each category lies in the goal assigned below it.



2.2.1 Academic Goals

As a researcher, I feel that one should continue their pursuit of learning. This learning helps improve the techniques available for water management, as well as staying informed about the current theories and frameworks available. Therefore, my academic goals is a continuing process of being informed about the latest in the field of water management to keep my work advanced. My academic goals, as mentioned above, falls into two categories: theory and methodology. This pursuit I feel, should not end with my PhD but continue to develop throughout my career

Theory

As an interdisciplinary research scientist, I feel that a strong theoretical foundation is essential, as well as being abreast of the newest theories in water management, with roots in economics, social sciences, hydrology and climate science. As new methods develop, reducing future uncertainties in climate, and therefore water supply, being acquainted with the most advanced theories is essential. I want to gain knowledge on the best available theories in water management in the food-energy-water nexus, and try to use those theories to develop my research.

Methodologies

Using some of the theoretical frameworks to develop sound methodologies is essential for water management. Within the food-energy-water nexus, there are always new theories and methodologies being developed, and being informed about them, and adopting the latest methods is critical for any researcher. This comes from being up to date in the field, and improving as I continue my research. This requires learning methods which I do not know of or do not have prior experience with. For example, the remote sensing class I pursued in the Fall Semester, 2018. As my work will be interdisciplinary, it also requires improving methodologies using hydrology, climate science, etc. and that requires me to always be informed about a wide range of topics. To achieve this, my PhD program allows me to sit in on classes for which an expertise is required. While I do not foresee taking more classes, this is something that is available to me right now.

Effective methodologies would also need to take into account external factors which affect water supply, for example, changes in population, consumption, temperature, precipitation, etc. Having taking courses in social sciences and environmental sciences has better prepared me to deal with such methodologies (further information in the next section), but I still feel that one can never stop learning. My natural curiosity will always keep me in the path of improving my understanding of the critical area of water management.

2.2.2. Research Goals

Within the food-energy-water nexus, new models are regularly being developed. Therefore, converting theories and methodologies into sound models requires a strong research background. Applying models to a case study and then understanding the impacts of changes from external factors will affect water supply and demand is critical (further explanation in initial dissertation plan). These models would also require data management and analysis, etc., sometimes of large amounts of data. Therefore, my research goals fall under the following categories: modeling & application, analysis & impacts, and recommendation & others.

Modeling and Application

My research goals here would require our theories and methods to be applicable, and modeling it to make it useable would be the first step. My goals are to develop coding and modeling knowledge of software like R, Python, and other relevant software to be able to generate results. A major aspect of this would include data. This include data collection (through field work, desk based research, stakeholder involvement, etc.), data management, and analysis of the results. This is a critical task, and the most time consuming. However, there are new packages being developed to better manage data, and reducing run time. Therefore, modeling my work is critical to achieve my goals. Effective models also tend to be most adoptable, as users fo not feel the need to learn new techniques, but just be allowed to run it.

Applying it to a case would help showcase the model, and its' effectiveness in managing water. An important aspect of water management model is to make it replicable and potentially scalable. My goal is to first, develop a model for water management which can be scaled at a national or regional level, without losing the local effects and drivers. Secondly, it should be replicable from one area to another, while being able to correctly represent the realities of other areas as well.

Analysis and Impacts

Analysis of the results and interpreting the results, so it is usable for policy and practice is very important as it helps understand the causes and effects. My goal is the most effectively analyze the results to better understand the impacts. Climate, population, and other drivers can negatively affect water supply and demand, which in effect, influences food and energy security. Therefore, understanding the impacts are critical (further explanation in the initial dissertation planning). Working with models which affectively translates into impacts is also important. I want to develop a better way to assess and communicate these impacts. This communication can be done in various ways, like publishing journal articles, workshops with stakeholders, press briefs, etc.

Recommendation and Others

The impacts of water management on society, economy, climate, etc. should then be formulated into concrete solutions. These solutions can be for policy, infrastructure,

sectors, etc. Looking at best-case scenarios and solutions for a similar challenge faced in other areas would also be needed. For example, shifts to sugarcane from other agricultural products are seen in Brazil, which has cause implications to water security in the country. Therefore, it is important to research and understand what solutions would work best in the area of study will be an important aspect to study.

Another important goal it to communicate, by publishing my work in journals, and presenting my results at conferences. This is important to get critical feedback for your work as well as to communicate your work to the scientific community.

2.2.3. Professional Goals

My professional goals also fall into the category of recommendations and others. This is because recommendations cannot be made without firstly, understanding the problem at hand, secondly, understanding the situation in the area of study, and finally, working with stakeholders who are directly involved with the work on the ground. This is because it is crucial to investigate how these models and results play out at the local level. This would require stakeholder engagement and dialogue and training or personnel to use the models. With these interactions, there are new ways to involve stakeholders, and to train users, at the lowest cost. It is also critical to involve the largest water using sectors, like agriculture, industry, etc. to get the most effective solutions.

As mentioned in my research goals, communication is an essential element. As a researcher, it is important to publish in scientific journals, but as a professional it is also important to communicate your information to the public, policy-makers and other important stakeholders involved in your work and/or affected by water management. Therefore, it is also essential to communicate using other means like press briefs, blogs, presentations, and other medium. This is something that I am interested in pursuing as a goal.

I also want to learn how to better teach students as well as adults in the techniques I have learned. With newer technology, teaching is not necessarily at a classroom level, and therefore, I want to learn different ways to teach and effectively communicate with students as well as professionals.

Finally, an important part of being a good researcher is to be able to generate funding for your research. To achieve this, grant writing is a key skill. While I have in the past, received funding from grants, the ways in which grants are being written, and the requirement of funding institutions are always changing. It is therefore of importance to keep improving my grant writing, as well as to be able to interact with the necessary funding agencies to receive funding. This is a goal of mine during and after my PhD.

My overall goal, along with my past experiences, current interests, and future plans can be seen in the schematic below. This represents all three goals, academic, research and professional.

OVERALL GOAL: To become a professor at a university or an independent researcher at a research institution in the field of water management

	PAST EXPERIENCES	CURRENT INTERESTS	FUTURE PLANS
ACADEMIC	• Economic techniques and theories • Climate and earth system science theories • Modeling • Teaching – Undergraduate Students	• Interdisciplinary methods and theories on water management • Improving methods for Water Management in the Food-Energy-Water Nexus	• Staying up-to-date with the newest theories in water management • Developing new methods for water management
RESEARCH	• Interdisciplinary research • Data management and analysis • Methodology development • Field based research • Literature review • Research writing • Modeling and machine learning	• Modeling and machine learning using interdisciplinary methods • Data collection and analysis (fieldwork and desk based) • Testing the models using Thailand as a case study	• Continue to improve models on water management using climate forecasts • Keeping my work relevant – by having it be scalable and replicable • Continuing the research in Thailand • Research writing
PROFESSIONAL	• Training • Stakeholder engagement • Event organization • Teaching – mid career professionals • Grant writing • Communication (press briefs, brochures, posters, oral presentation) • Project Management	• Training • Stakeholder dialogue • Grant writing	• Grant writing • Communication • Newer techniques to train and teach

3. Coursework Experience and Plans

3.1. List of Courses Undertaken

3.1.1. Environmental and Biological Aspects of Earth Systems Science

Name of Course	Program of Study
Dynamics of Climate Variability and Climate Change	MA Climate and Society
Quantitative Models of Climate-Sensitive Natural and Human Systems	MA Climate and Society
Regional Dynamics, Climate and Climate Impacts	MA Climate and Society

3.1.2. Human Dimensions of Global Change

Name of Course	Program of Study
Managing and Adapting to Climate Change	MA Climate and Society
Application in Climate and Society	MA Climate and Society
Global Governance for Sustainable Development	MA Climate and Society
Political Economy for Energy and Climate Change Policies	MA Climate and Society
Economics and Finance of Climate Change	MSc Economics
Economics of Health and Environment	MSc Economics
Techniques for Environmental Valuation	MSc Economics
Macro Economic Theory	MSc Economics
Microeconomics	MSc Economics
Environment and Economic Development	MSc Economics
Theory of Environmental Policy	MSc Economics
Economics of Natural Resources	MSc Economics
Trade and Environment	MSc Economics
Collective Action and Environmental Management	MSc Economics
Public Economics	MSc Economics

3.1.3. Technical Courses

Name of Course	Program of Study
Land Cover Characterization Using Multi-Spectral Remotely Sensed Datasets	PhD Geographical Sciences
Topics in Data Visualization with Processing and Applications in R	PhD Geographical Sciences
Introductory Python **(NO CREDITS)**	PhD Geographical Sciences
Quantitative Models of Climate-Sensitive Natural and Human Systems **(REPEATED)** – Included Matlab	MA Climate and Society
Quantitative Methods	MSc Economics
Econometrics	MSc Economics
Econometric Methods (Advanced Course) – Included Stata	MSc Economics

3.2. Description of Past Coursework in Achieving Goals

The courses I have undertaken in the past, and at the University of Maryland in the past semester have helped me become a better interdisciplinary academic and researcher. Through my coursework, I have gained exposure to a wide range of topics in earth and environmental science, economics, policy, etc. I have also been able to apply many of the theories, methods, and techniques learned in my class in my research.

My self-reflective description of my past coursework has been divided into the three aspects of geographical sciences to also represent how they also represent my preparedness in the discipline of geography, and how it will help me achieve my academic, research and professional goals

3.2.1. Environmental and Biological Aspects of Earth Systems Science

Prior to my Masters in Climate and Society, most my work focused on resource and development economics, and lacking an interdisciplinary approach to research. Since then, my coursework has opened me up to using tools and techniques I did not know how to use, and its fundamental need in the field of resource management. The Masters in Climate and Society helped me with just that. Since then, during my work at the Columbia Water Center, I not just developed interdisciplinary models which used forecasts, but also used Nonhomogeneous Hidden Markov Models (NHMM) to make precipitation forecasts and K-nearest neighbors (KNN) to make streamflow forecasts (more details in further sections).

These were techniques and theories I learned through my coursework during my Masters in Climate and Society

Food, energy, and water are heavily influenced by temperature and rainfall changes, and therefore, predicting the future with higher certainty is very critical in this field. My coursework is going to help me in this work. It will help me develop an integrated modeling framework which uses climate forecasts to make water management decisions.

Since both floods, and droughts can influence water, food and energy security, it is important to look at the different aspects of rainfall change. These are courses that I have been able to take in my coursework to better understand the influence of climate dynamics on economy and society.

3.2.2. Human Dimensions of Global Change

My Masters in Economics and specific course during my Masters in Climate and Society have helped me greatly. In my past work, I have used many methods in economics, policy, and modeling which used the theories I learned in my coursework.

Similarly, there are many aspects of the human dimensions which affect the food, energy and water systems. Urbanization, economic development, population growth, etc. Through my coursework, I have learned many theories to tackle these topics, and have used them in my work on water management in the past. I have also used many of the things I have learned during my coursework into my research at The Energy and Resources Institute in India and at the Columbia Water Center.

3.2.3. Technical Courses

Some of the most important knowledge I have gained through my coursework are the technical courses. I initially began with econometrics during my masters, following which I used it in my work on resource and development economics. During my masters in Climate and Society, I learned how to use Matlab, which is what I initially used to develop my model for reservoir optimization at the Columbia Water Center, before shifting to using R. The exposure of one software led me to another, which has been a great advantage to the work I do now. During the winter, I observed a python class at the University of Maryland. During my *Land Cover Characterization Using Multi-Spectral Remotely Sensed Datasets*, I gained exposure to remote sensing and GIS techniques. Having never used remote sensing tools, this class helped me understand the importance and value of using satellite based data for water management, especially when there is lack of data. The class titled *Topics in Data Visualization with Processing and Applications in R* taught me improved ways to visualize data on R and I learned many new packages which I could use in the future.
Modeling water supply and demand using forecasts requires a good knowledge of theories, but also a very strong understanding of programming software. My past courses have helped me steer a career in modeling, programming and machine learning, which is a part of my goal.

4. Research Experience and Plans

4.1. Description of Past Research in Achieving Goals

Through my past research work, I have gained a wide range of experience and exposure to the field of water management and the broad field of resource management. While my initial research work was focused on resource and development economics, I have been conducting interdisciplinary research in water management since 2013-14. My research work is divided into the three sections of past research work, my work as a Staff Associate at the Columbia Water Center, my work as a Research Associate at The Energy and Resources Institute, and other relevant research I have conducted in the past. Finally, I will briefly mention the research work I am currently doing as a Research Assistant with Dr. Varaprasad Bandaru at the University of Maryland.

Columbia Water Center

During my research at the Columbia Water Center, I looked at theories which have worked in the management of water supply from reservoirs given streamflow forecasts. This required an extensive literature review of the models and methods that existed in the past. Following this, I developed a new method to optimize water supply, given demand from different sources, with a high cost of failing to provide water, or water deficit, given streamflow forecasts. During this part of my research I learned how to do literature review, instrument and method development, data collection and analysis, and research writing.

I also developed streamflow forecasts using K-nearest neighbor and rainfall forecasts using Nonhomogeneous Hidden Markov Model (NHMM). Both required method development, data collection, cleaning and analysis, and research writing. Another important aspect of the NHMM was to do analysis to find the number of hidden states and the predictors affecting rainfall. This not just required a broad literature review, but also a lot of data analysis to find the best predictors.

My work here also helped me with programming and also developed a matrix generator which can be used to solve linear problems on R. I also learned research writing by writing a paper on reservoir optimization and presenting my work at AGU and EGU.

The Energy and Resources Institute (TERI)

My work at TERI included various research projects which helped me gain a wide range of experience and expertise. I am focusing on a few research activities, as there were many research projects where I developed similar expertise. During my work on the TERI Environmental Survey, a survey in the six largest cities in India to assess people's perception, awareness and attitudes towards the environment, I learned how to create questionnaires, test them, conduct the surveys, collect data and analyze it. I also wrote reports, organized events, and wrote press releases. During my research on sustainability of organic agriculture, I developed competence in field research, including conducting face-to-face interviews, focused group discussions, and open ended questionnaires to gather both, quantitative and qualitative data on farmers interested in, their willingness to and barriers

in shifting too organic agriculture methods. I also wrote planning reports for the Ministry of Agriculture, Government of India. My research on resource efficiency included data collection, report writing, etc. My research on second generation biofuels included data collection and analysis using field based work, which included farmers willingness to sell crop residue using a rank based questionnaire to gather quantitative data for willingness. For two of my research projects, the TERI Environmental Survey, and another on Sustainable Development Goals, I also wrote grants and successfully received funding.

Others

Some of the other relevant research I have included research assistant work, and internships. I worked at the United Nations Development Program, Delhi while writing my Master's thesis on gender and climate change, which was a review paper on effects of climate on gender. During another internship at the International Policy Center for Inclusive Growth, UNDP, Brazil, I worked on data collection and analysis to study the state of inclusive growth over time in different developing countries around the world. During my summer research at the University of West Indies, Jamaica, in collaboration with Columbia University, I conducted stakeholder interviews with producers of rainfall and temperature forecasts and the organizations who would disseminate this information to farmers. The research also included developing open ended questionnaires for these stakeholders, and analyzing the results. Finally, I worked with Prof. John Mutter at Columbia University twice, firstly, with him on collecting data and doing some regression to find the relationship between disaster mortality and development indicators like HDI, GNI, etc. in countries. I also helped him edit his book titled *The Disaster Profiteers: How Natural Disasters Make the Rich Richer and the Poor Even Poorer* published by St. Martin's Press.

Current Work

I have begun the literature review on the shifts from rice to sugarcane farming in Thailand, which is my area of study. I have completed the first draft of a review paper on residue burning and shifts from rice to sugarcane farming and its' social and economic effects in Thailand. The paper also includes the challenges Thailand faces, along with strategies to overcome some of the challenges. I have also started the research on the effects of production and yield due to droughts in Thailand. In the next few months, I will be developing the model for the research.

4.2. Additional Preparation Required

I am currently working on the literature review on Thailand to understand the challenges in hand. With the new policies, there are shifts in crop production, population increase is making this an increasing challenge, especially with regard to water management in the FEW nexus (further information in initial dissertation planning). Therefore there is more literature review to be conducted.

Additionally, there is a need for model development and data collection. Preparation for this would be to develop a sound model on R, and to find the best packages to manage the data, run the model, generate results, and visualize and analyze the data.

Working on my research on Thailand will help me achieve the competence required to reach my future goals.

4.3. Planned Future Research Activities

Literature Review

I will continue for a few more weeks to do literature review on the food-energy-water nexus, to understand the challenges in Thailand, and for the development of the model. The general consensus (showcased in section 7) is that there are significant impacts of the Alternative Energy Development Policy, which has led to an increase in production of sugarcane and a drop in rice production. Another significant finding is the impact the 2014 drought had on sugarcane and rice production. This shows the importance of the FEW nexus in Thailand, and in particular, water management and rainfall predictions in ensuring food, energy and water security.

Method Development

I will be developing the method using the Equilibrium Displacement Mathematical Programming (EDMP) Model, and the input-output model. The method, while has already been developed, would require the method to be adjusted to the Thailand case, and for the shits in production of rice to sugarcane farming.

Data Collection (field work and desk based)

I hope to spend the summer collecting data in the field in two provinces in Northeast Thailand, and meeting with stakeholders to gather data. Additionally I will also be doing an extensive internet search to get the data, along with getting data from other colleagues at the University of Maryland.

Modeling

I will work on developing the model on R, and running it with the data collected for Thailand

Results, Analysis and Recommendations

Following the model run, I will work on the results and analysis of the research. I am also hoping that the travel to Thailand will help in connecting with some local partners who would help in giving concrete recommendations and also advising what would work the best for the case of Thailand.

Research Writing and Presentations

With my goal to continue in the field of research, I look to continue publishing and presenting my results at conferences. Some of the conferences could potentially include the European Geosciences Union, American Geophysical Union, and the American Association of Geographers conferences. The first review paper is in the works, and I hope to get that published soon. I also hope to complete the model, and be able to present a poster in April for the NASA Project Annual Review.

Technological Application

If necessary and relevant, the model could also be published on R Shiny, which would help other users to run the model for their case.

4.4. List of Significant Research Outputs

White, I, Lawless, KL, Vivoni, ER, Nascaro, G, Pahle, R, **Kumar, I,** Coli, P, Castillo, RM, Moreda, F, Asfora, M (2018) *Co-Producing Interdisciplinary Knowledge and Action for Sustainable Water Governance: Lessons from the Development of a Water Resources Decision Support System in Pernambuco, Brazil*. Global Challenges. DOI: 10.1002/gch2.201800012

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Kumar, I, Josset, L, Lall, U, Silva, EC, Possas, JMC, Asfora MC (2017) "*Cost Optimization of Water Resources in Pernambuco, Brazil: Valuing Future Infrastructure and Climate Forecasts*" Geophysical Research Abstracts Vol. 19, EGU2017-10147, 2017. EGU General Assembly 2017

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IFEU-Institut et. al., TERI, GIZ (2013), *India's Future Needs for Resources, Dimensions, Challenges and Possible Solutions*. TERI, GIZ, IFEU *Heidelberg, Delhi* **(Consortium Member)** Available at:

Additionally, I have also submitted technical reports for my research to the funding agencies like IDB, DFID, etc.

5. Professional Experiences

Presentations, Training and Teaching

1. Presented my work on reservoir optimization and the Nonhomogeneous Hidden Markov Model at the First Meeting of the Community of Practice of the Hydro-BID Support Center (CeSH) titled *Water Security in LAC: Tools to Support Water Resource Management and Extreme Events* held in Lima in 2017.

2. Trained government officials and policy makers on the reservoir optimization model and the Nonhomogeneous Hidden Markov Model from the Pernambuco State Agency for Climate and Water (APAC - Agência Pernambucana de Águas e Clima), the state water utility COMPESA (Companhia Pernambucana de Saneamento), Federal University of Pernambuco, and other policy makers from other agencies in the State Government of Pernambuco.

3. Helped develop a course for the *Indian Technical & Economic Cooperation Programme (ITEC), Special Commonwealth Assistance for Africa Programme (SCAAP)* funded by the Ministry of External Affairs, Government of India on *Resource scarcity and governance: issues and challenges*. I also helped write the grant and taught some courses in the program.

4. Helped develop a course for an online course funded by the World Bank on *Policies and Practices for Natural Resources Management*. I also helped write the grant, taught one section, and helped manage the question and answer section of the course.

Others

1. Developed an online interface for the reservoir optimization model on R Shiny, which can be used freely by policymakers and practitioners. The code for the model is also available freely on github

2. Organized multiple events through the course of my research work at the Columbia Water Center and TERI. Some of those include

   a. Rio+20 side event: On "Civil Society and Knowledge Networks: Dialogues around Institutional Framework for Sustainable Development" in collaboration with UNDP/IPC-IG, Brazil.

   b. Sustainable Development Goals (SDGs): Organized an international seminar on SDGs.

   c. TERI Environmental Survey: Organized launches as part of the research in Delhi and Mumbai.

   d. Organized and Co-Moderated session on "Biomass Conversion and Use" at the "International Workshop on Shaping the Future of Advanced Bio-refining for Modern Societies" held in 2013 in Brussels.

6. Evidence of Analytical and Integrative Thinking

As a lot of my research had overlapped, I feel that I will combine the products into my overall research projects to showcase the evidence of analytical and integrative thinking. This is not an exhaustive list.

Reservoir Optimization and Rainfall Forecasting for the State of Pernambuco (Scholarly Products include reports, conference posters, etc.)

The real-world challenge in Pernambuco was that it has (at the beginning of the project) been in a 4 year long drought, and their reservoirs were emptying out. The solution to this was to receive water from trucks at 3-10 times the normal cost of water supply per cubic meter. The water utility also did not use any reservoir rules or use forecasts to make decisions on water supply. The challenge here was to develop a reservoir optimization model which could help optimize water supply by using forecasts and reducing deficit. To achieve this, I developed a reservoir optimization model, which used streamflow forecasts to reduce the costs of water supply. The model needed monthly forecasts, which were not available, I also developed a rainfall forecast model using Nonhomogeneous Hidden Markov Model. I also used K-nearest neighbor to make streamflow forecasts. These results were eventually used in the reservoir optimization model. The results showed that the model was effectively able to predict droughts and reduce costs of water supply by reducing failure. The model also helped understand the value of future infrastructure being built by running scenarios with the future infrastructure. Pernambuco state will be receiving extra water from the Rio Sao Francisco, which has a fixed and variable cost of supply of water yearly with an upper limit. This future infrastructure was taken into consideration as it would have its own pipelines and water treatment facilities. The research showed that Pernambuco, a state with historical droughts, and a future with ~60% reduction in precipitation by the end of the century would require drastic changes in consumption, rather than newer infrastructure coming in to a dry region with high evapotranspiration.

This research helped me in developing very strong skills in various aspects, and helped with a region dealing with real challenges of water management. While the challenge is not similar for Thailand, the approach to research is very similar to what I wish to pursue during my PhD.

TERI Environmental Survey

The TERI Environmental Survey, which I wrote and successfully received a grant for, was another research which showcases my analytical and integrative thinking. The research was conducted in the 6 largest cities by population to understand the awareness perception and attitude of people towards the environment. The research included developing the questionnaire, testing it, sample selection (stratified random sampling), surveys, data management, and analyzing results. There were over 4000 results from the 6 cities, which were representative of the population of each city and stratified by the income groups. This helped with proper representation of the different sections of each city. During the research,

while I managed a large team, I was responsible for the development of the questionnaire, monitoring of the survey, report writing, press releases, etc.

Second generation biofuels

A good evidence of analytical and integrative thinking done in this research was trying to develop a rank based questionnaire which helped convert qualitative willingness data to a rank based system. Willingness of farmers to sell their crop residue (rather than burning it) is not easy to capture, and is generally done using open-ended questionnaires. Therefore, using this methodology to analyze and represent farmer willingness and barriers to selling residue was useful as we were able to quantify the qualitative data.

Organic Agriculture

The organic agriculture research helped me develop multiple questionnaires and fieldwork techniques, to gather both, qualitative and quantitative data. This was another survey to understand farmer willingness to shift to organic farming. This was another research which helped develop my analytical and integrative thinking by trying to find what information we could gather in a questionnaire format, and which we could gather through open ended questionnaires.

Overall, I feel that through my research, I have the capacity to conduct research through the processes I have used in the past to effectively and timely complete my research.

7. Initial Dissertation Planning

7.1. Real World Problem

As we try to maintain the food and energy security, water management is a critical component. This becomes especially important in the light of climate change, increasing demand for water, and sectoral shifts in demand. This is pertinent in regions where production is moving from food to energy, as nations seek to reduce their reliance on imports of energy. At the same time, climate models which forecast rainfall and streamflow are improving and reducing uncertainties (Lemos et. al., 2012). These forecasts can be used to improve water management, and models associated with them. Achieving food and energy security has led to competition for land in many parts of the world. This leads to shifts in water use and demand, which, through management models, can continue to work at an optimal state. Climate variability represents a physical and financial challenge for the operators of a water system. The use of probabilistic streamflow and water demand forecasts can help formulate better operational and financial management strategies.

Despite these challenges and improvements in forecasts, water managers and policy makes have been slow in adopting these models. The motivation of using such a model is to help build financially resilient operation methods with lower uncertainty and to reduce water deficit. While these models are important, very few exist (Lu, et al., 2017; Sankarasubramanian et. al., 2012), and fewer being used. These models help in making more informed decisions on policy and to facilitate development of future infrastructure. To achieve this, a modeling framework needs to be developed which uses forecasts of rainfall and streamflow to optimally manage water given the shifts in the demand and supply of water, especially pertaining to the food-energy-water (FEW) nexus. This model should account for sectoral water supply given the current and future demand changes. A multi-reservoir, multi-region and multi-use optimization model that addresses these issues provides a practical tool for its operation. A case study for the model would be developed for Thailand, where the Government of Thailand is looking to replace rice production for food to sugarcane production for energy to make their country more energy secure (DEDE, n.d). The rationale for this policy, according to Wattana (2014), comes from the perspective of energy security, environmental concerns, and enhancement of rural development.

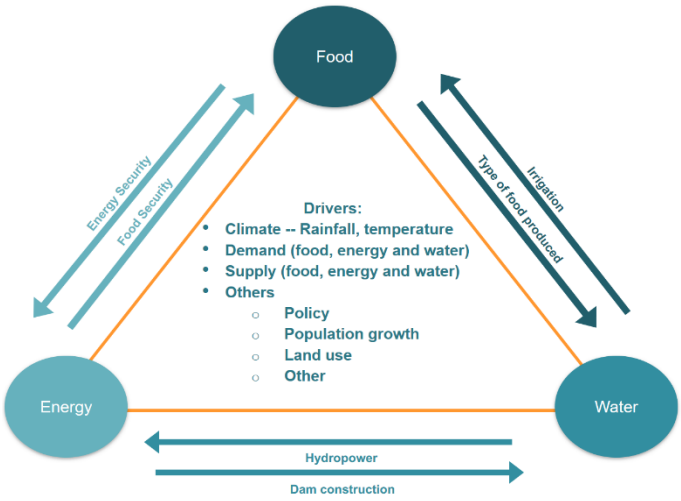

Figure 1: The Food-Energy-Water (FEW) Nexus, trade-offs and drivers of change

The FEW Nexus, which is driven by climate, demand, supply and other (policy, population growth, land use, etc.) factors, is an important aspect to study, because, to achieve security in one of the three, there are tradeoffs with the others. It can be seen in Figure 1. For each sector, a balance needs to be achieved, as growing one sector directly affects the other two.

In Thailand, agriculture accounts for 114 billion m3 of water annually, whereas demand for industry and domestic consumption accounts for 11 billion m3 and 27 billion m3 for maintaining the ecosystem (Apipattanavis, Ketpratoo & Kladkempetch, 2018). With 75% of the water demand coming from agriculture, the importance of water management in that sector is critical.

A study in the upper Chao Phraya River Basin (Ping River Basin) in Thailand, the largest river basin in the country, is expected to see a decreasing trend in summer monsoon rainfall (Singhrattna & Babel, 2011). The study also showed that there are expected to be an increase in the frequency of extreme events (dry and wet). In general (excluding the A2 IPCC scenario), the dry events showed a greater chance of occurrence than climatology, while wet events showed a decreasing chance of occurrence. In the Northeast of Thailand, similar changes are seen, and water stress is seen in the Chi and Mun watershed (Silalertruksa et. al., 2017), although not as extreme as the Chao Phraya River Basin.

While there has been a reduction in the expansion of irrigated areas, as a result of lack of water resources, demand from the population for drinking water and agricultural production has increased, With increasing demand, Thailand would need 5 billion m3 more water by 2027 (Apipattanavis, Ketpratoo & Kladkempetch, 2018).

Thailand, as a part of their 10-year Alternative Energy Development Plan (AEDP), seeks to reduce their reliance on energy import, by promoting alternative energy usage to 25% by 2021 (DEDE, n.d.). To achieve their goal, there is an expectation to increase the production of sugarcane. As a result of the AEDP, since 2012, the year of its implementation, rice production (in and off season paddy) has fallen, and sugarcane production has risen, as seen in Figure 2, with the first vertical line representing the year the policy began. A very significant link between water security and food and energy security can be seen in the case of the second vertical line, where the production of sugarcane suddenly dropped. This is a direct effect of the drought which hit Thailand in 2014. This shows the importance of managing water for food and energy security. For such a case, the FEW nexus is of high importance, as policy and climate are leading to a strong changes, which will affect both, demand and supply of food, energy and water. This is expressed in the paper by Wattana (2014), where the author mentions concerns of food versus fuel dilemma, issues related to land use for biofuel production, and talks about water security concerns, in which Thailand is prone to not just droughts, but also flooding incidences.

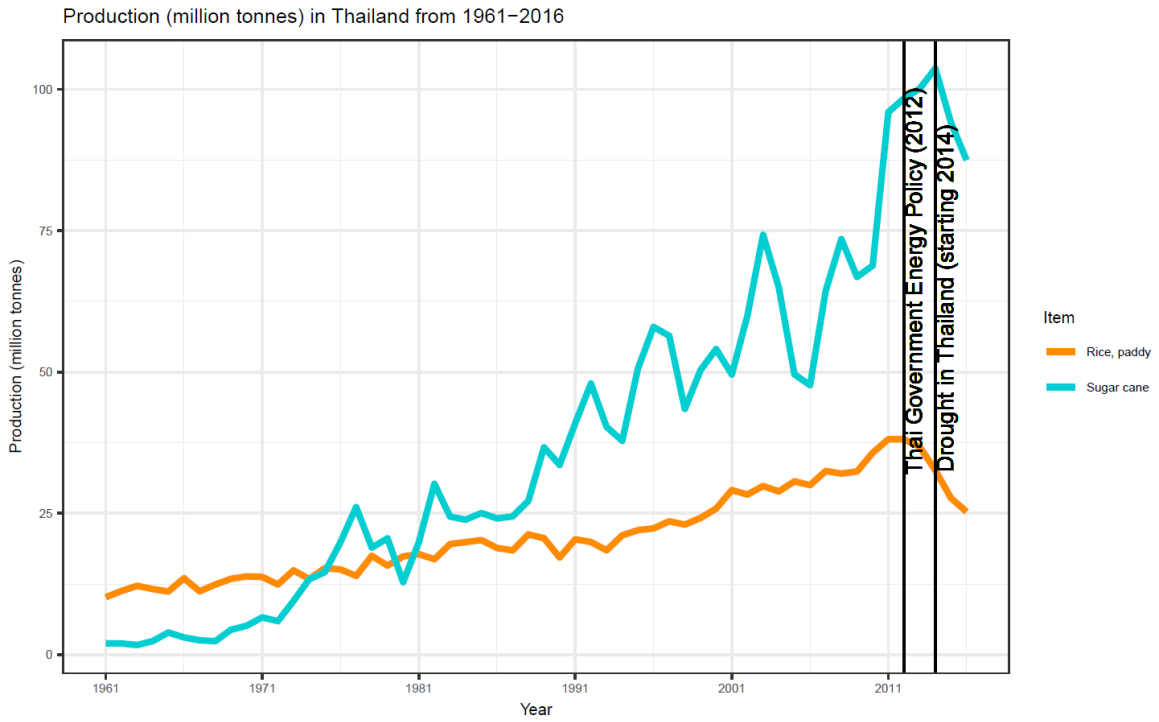

Figure 2: Production of rice (on and off season paddy) and sugarcane (2011-2017). Source: FAOStat

The study therefore proposes a case study in the province of Chaiyaphum and Nakhon-Ratchasima, which are both a part of the Northeast region of Thailand to test the model. Chaiyaphum receives water from the Chi Watershed, while Nakhon Ratchasima receives water from the Chi and Mun Watershed (Silalertruksa et. al., 2017). The site selection is in the Northeast Thailand, as it is the agricultural production regions of the country, with the largest harvested area of rice in the country (ADB, 2012).

7.2. Research Objectives and Questions

The overall objective of the research is to develop water management model, which uses forecasts to better manage water supply within the FEW nexus. The model would be available through the RShiny online interface, and would allow users from other regions to the specific steps associated with the research objectives are outlined below.

Objective 1: Develop a probabilistic rainfall and streamflow forecast to assess the spatial and temporal (seasonal and interannual) changes in water supply.

- Develop a model to make rainfall and streamflow predictions to use in the water management model using K-nearest neighbor
    - Reduction in rainfall amount and changes in the seasonality can reduce and alter water supply, affecting crop production.
    - Changes will also affect hydropower production in the region

Objective 2: Use the forecasts in an Equilibrium Displacement Mathematical Programming (EDMP) Model and Input-Output Model to optimally manage water supply, given the demand from different sectors, and changing patterns of demand

- This model would be looking into the FEW nexus as shifts in food to energy would change demand patterns, and water use.
    - Shifts from rice to sugarcane farming will cause water use change
    - Reduction in water availability will affect both, food and energy security
    - The model developed here, will enumerate the effects of such shifting patterns on water, food, and energy.
    - The results would include the allocation of water over time to different users, the deficit of water supply, and where the deficit occurs
- The model results would also help in identifying areas of concern

Objective 3: Use the results to make informed decisions and recommendations on water management through infrastructural development and policy for the case of Thailand, and contribute to the Sustainable Development Goals

- Given the importance of food, energy and water security in the Sustainable Development Goals, this research will help contribute to model development to achieve these goals
- The case for Thailand would also include recommendations for policy planning and infrastructure for the case study in Thailand

The conceptual framework, as seen in Figure 3, highlights the key drivers of change in the FEW Nexus. The objectives, written down at the bottom, are associated with the different drivers of change. Each driver has questions associated with them, which would be answered through the model development and results. The final objective would be a culmination of all the results from the models.

In figure 3, each supply driver affects the demand driver, i.e. water supply and demand are affecting each other, similarly for food and energy supply and demand. In the case of Thailand, the AEDP (Energy policy) affect food and energy supply as there is an added competition for land to produce rice for food, or sugarcane for energy.

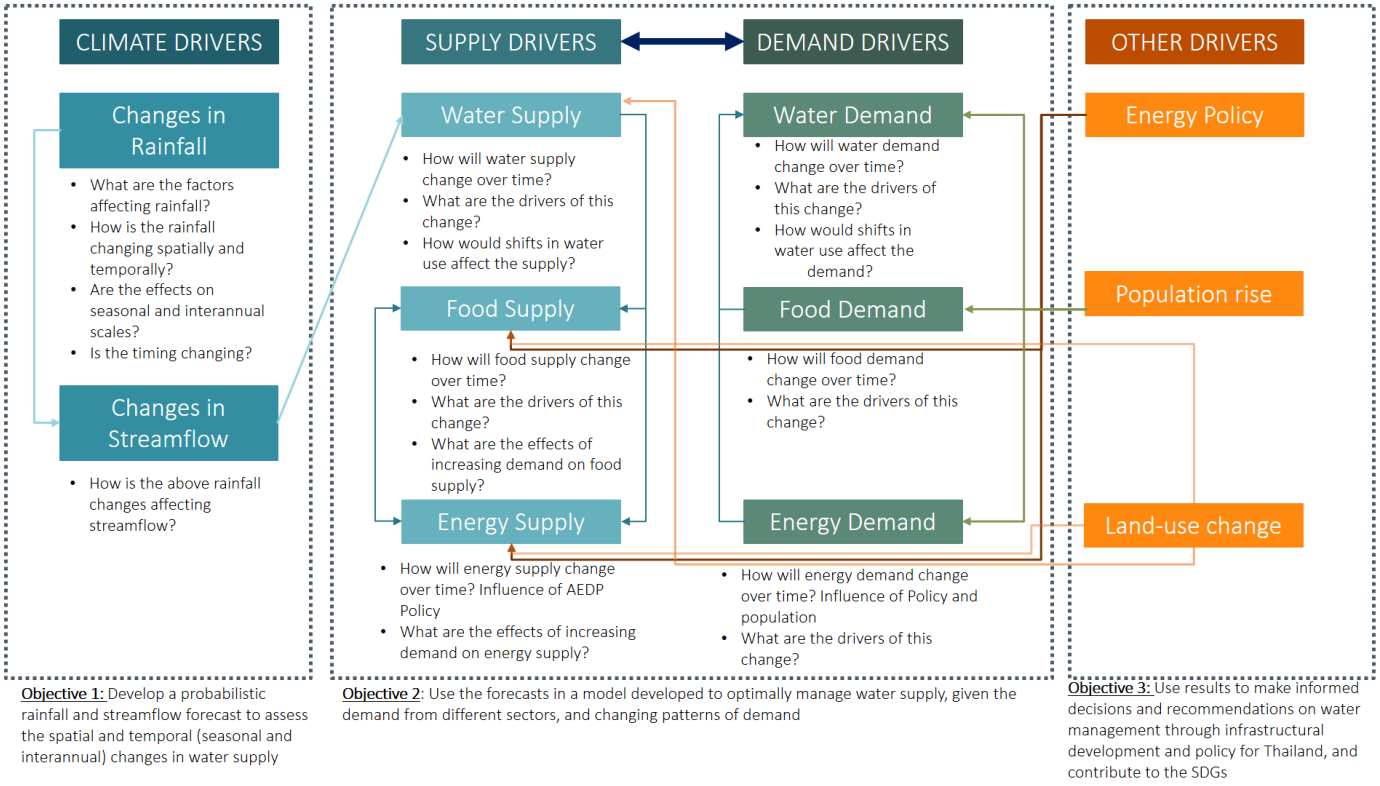

Figure 3: Conceptual Model Framework, Objectives, and Research Questions

7.3. Theories, Concepts, Research Literatures, and Methodological Approaches

Climate Models

The forecasts are developed using K-nearest neighbors (KNN) ensemble simulations as described in Nowak et. al. (2010) and Lall and Sharma (1996) is used. The K neighbors are selected based on the distance from the observed streamflow for the present year and applied to select the flows for the next year. Let Q_t be the vector of streamflow at the M reservoir inflow sites for the current year t, and d_{tj} be the Euclidean distance between this flow vector and the flow vector Q_j for the j^{th} historical year. Then the historical years that are the k-nearest neighbors of year t, are identified as the years with the K smallest d_{tj} values. The probability that the i^{th} neighbor represents current conditions defined as:

$$W(i) = \left(\frac{1}{i}\right) \Big/ \sum_{i=1}^{K} \frac{1}{i}$$

One of the historical years, j', that was a k-nearest neighbor is then randomly drawn using this probability metric, and the corresponding forecast for the next years reservoir inflows is then $Q_{j'+1}$.

Rainfall Forecast Model

Station level data would use predictors to make seasonal rainfall forecasts, using predictors which affect the rainfall in the region, using correlation, principal component analysis, etc. Rainfall directly affects water supply, which would be an important component of streamflow forecasts. A study by Singhrattna et al. (2005), show that ENSO shows high relation with the summer monsoon with Thailand. Other correlation would also be tested for the study.

Streamflow Forecast Model

The rainfall forecast model would then be used as a predictor for streamflow forecast. Streamflow is important to understand the water availability for crop production, whether for food or fuel. The streamflow will also affect other factors, like hydropower potential, another one of the AEDP Policy. Forecasts would also help in understanding the infrastructure potential, as explained above, expansion of irrigated area is affected by the reduction in water supply.

Equilibrium Displacement Mathematical Programming (EDMP) Model and Input-Output Model

The Input-Output model helps understand change in inputs (in this case, water supply) affecting the demand (for agriculture and energy production). The EDMP Model will then use the input-output model to aid in providing a sector-wide analysis of production and distribution of commodities (food and fuel). The model includes five categories: farm sector use, domestic demand, export and import, and change in storage. Initially developed by the USDA (Harrington & Dubman, 2008), has also been applied to assess climate change impact on water resources and agriculture in Colorado (Gunter et al., 2012; Bauman et. al., 2014; Fathelrahman et. al., 2014). However, the models are yet to look at energy production, and the shifts from food to energy. Therefore, the model developed here would also look into the patterns of shift from food to energy as well as develop a framework which uses this model to estimate future availability of water, food and energy in Thailand. This is a critical element, as there are competition for food and fuel in many parts of the world and similarly, changing rainfall patterns are affecting water supply. The results would then aid policy recommendations in Objective 3.

7.4. Dissertation Committee

For my dissertation committee, I need committee members from three research themes

1. Economics (Laixiang Sun, Klaus Hubacek)
2. Climate Science (TBA)
3. Hydrology (Fernando Miralles-Wilhelm, Upmanu Lall?)

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