

WF23\230168

Sustainability of Agrarian Societies in the Lake Chad Basin

Section 1 - Research Proposal

Subject Area

Economics

Subject Area Detail - Economics

Please select the detail(s) of your Subject Area:

- Agricultural Economics
- Overseas Economics
- Quantitative Economics

Title of Research Proposal

Please state the title of your proposed research:

Sustainability of Agrarian Societies in the Lake Chad Basin

Abstract

Please provide a short abstract summarising your proposed research in terms suitable for an informed general audience, not one specialised in your field:

Lake Chad, a great body of fresh water in semi-arid North Central Africa, is critically important for millions of people in this impoverished region. The lake's levels have varied dramatically over many decades. The region's farmers, fishermen, and pastoralists have adapted to these extreme changes, including devastating droughts in the 1970s and 1980s. Many governments and international authorities believe that Lake Chad is drying out due to climate change, though this is not supported by published data or studies. We propose to study how Lake Chad's agrarian societies in Nigeria have operated over the long term, the value of ecosystem services they draw, and whether their path is sustainable to 2100 under realistic population increase climate scenarios. Working with African colleagues and local stakeholders, including village chiefs and elders, we will curate a comprehensive climate and agriculture dataset, and analyse it using probability models and Bayesian statistics.

Proposed Research Programme

Please give a detailed description of the research programme, including methodology:

Applicants should be aware of the importance that assessors place on the viability, specificity and originality of the research programme and of its achievability within the timescale, which should be specified in the Plan of Action.

Lake Chad is a great shallow land-locked freshwater lake in Africa's Eastern Sahel. It is critically important to the livelihoods of millions who inhabit this remote and least developed region. The lake's levels have varied dramatically often from one year to the next, over many decades, and perhaps many centuries, and from the wet season to the dry season ever year. Throughout this uncertainty, the area's farmers, fishermen, and pastoralists, have demonstrably adapted to these extreme changes, adopting various agrarian activities to take advantage of every weather and seasonal condition. Two severe multi-year droughts in the 1970s and 1980s, which affected the entire Sahel, severely dried out Lake Chad by 1984. Beyond these, food security has not been reported as a major problem in the Lake Chad Basin (LCB), despite what looks on paper like extreme poverty.

Still, many heads of state, their cabinets, and Western and UN-led aid organisations have presumed that Lake Chad is relentlessly drying out, due to global climate change, an assessment which is quoted routinely in reputable media (BBC, 2018; UN Africa Renewal, 2019; New Yorker, 2017; New York Times, 2017; Wilson Center, 2020).

But the data does not support this assessment. Since 1995, the lake has not been drying out (Bader et al., 2011; Climate Change News, 2019). Satellite data shows it has stabilised at a level which is low (Vivekandanda et al. 2019) but which provides ecosystem services far greater than those attained during the 1980s' drought (Lemoalle, Magrin, 2014). Preliminary statistical modeling work by our proposed lead collaborator Frederi Viens (Viens, 2019), based on hydrological data from Bader et al., 2011, rejects a direct connection to global climate change.

We propose to adapt and improve on the tools used in Viens (2019), namely stochastic modeling and computational Bayesian statistics, a form of supervised machine learning, to build and analyse explanatory and predictive models of lake levels as they respond to weather and climate variables, and local agricultural activity. Viens (2019) points to an agrarian system that may have been environmentally sustainable over many decades or even centuries. This is corroborated by first-hand accounts (e.g. Batello et al., 2004).

By performing an economic analysis of the LCB's ecosystem services valuation, from the perspective of agrarian societies, over the long term, we will investigate quantitatively whether this sustainability may now be at risk, and draw probabilistic predictions to year 2100 under realistic climate change and population pressure scenarios. The data needed for this analysis, much already in our possession, covers lake and basin hydrology, agricultural production, climate reconstructions, and local stakeholder practices and needs. The latter will be developed in our programme.

To determine whether a direct past connection to climate change may be rejected, while carefully assessing the effect of inevitable future climate disruptions on LCB agrarian livelihoods, we will build on our groundbreaking statistical inference work (Ernst et al., 2017a) published in *The Annals of Statistics* (the leading academic journal in the field), which provides precise mathematical answers to how to evaluate the correlation of non-stationary time series. Our framework of stochastic modeling and Bayesian statistics will allow a full quantification of uncertainty, providing unambiguous probabilistic answers to questions about future scenarios or frequency of desirable or adverse events, and allowing us to estimate what value farmers can expect for the LCB's ecosystem services from their perspective, to 2100. More technical details are given below.

Our broader societal motivations are ambitious, with a goal to lay the groundwork for making fact-based recommendations to policy makers, on how to support LCB's millions who are vulnerable to climate shocks, and whose food and water security are not well understood. Academic work based on current data may fall short of the impact and attention the rural populations of Northeast Nigeria deserve, and have never received.

We plan to run large-scale rural surveys, with the collaboration of a team of research colleagues in Nigeria, and their MS-level research assistants. We will connect with agrarian stakeholders around Maiduguri, Borno state's capital region, the heart of Nigeria's LCB. We will learn about rural day-to-day and year-to-year challenges, what simple improvements could help farmers' and pastoralists' operations in their opinions, what traditional techniques and strategies they use to handle weather and climate uncertainty, and we will reconnect with them near the end of our project, reporting back our findings and recommendations, and informing them of what leverage, if any, we all may have on their region's public administration.

The LCB environment is among the most challenging and unpredictable on earth. Agrarian societies there have managed those risks for decades, and we must learn, through direct engagement with them, how they view the probabilistic decision-making which they face every season. We must translate our findings into their decision framework. My proposed lead collaborator's extensive experience with farmer-centric agriculture science, including in Africa (Viens, 2019; Wang et al., 2019; Tu et al., 2022), will help, as will the commitment we have

received from Nigerian collaborators including in Borno state. Completing these tasks would constitute a high level of engagement success. With the support of the British Academy, contact with these rural stakeholders is certain to occur, as is success in running meaningful rural surveys.

Another aspect of engagement is to raise awareness among Nigerian academics and government decision makers that the rural populations of Nigeria's LCB are not forgotten by the outside world. We also wish to help ensure that agro-ecological sustainability in the LCB remains a meaningful question. We expect success in this direction, thanks to our connections within Nigeria's Ministry of Agriculture. Our work will require the assistance of MS-trained data management and analysis collaborators in Nigeria. Our main collaborators there have committed access to this workforce. These talented young minds are often destined for careers as scientists and technicians in Nigeria's public service; implementing training protocols for them is a further aspect of our public scientific engagement.

Here are specific contexts and questions about the LCB and its people, which we will answer probabilistically.

In recent decades, for part of any year, the north and south sides of Lake Chad are separated by a Great Barrier, with channels allowing water to replenish the north when the south side is full enough. Inflow from the Yobe river in the north is secondary to this process (Bader et al., 2011). The South side, fed by the powerful Chari river, has perhaps a million acres of wetlands, and a great pool of open waters, even in dry years. Inhabitants of Nigeria's Yobe River sub-basin, including Borno state, are much more vulnerable to lake variations than elsewhere in the LCB. The Borno state, home to millions who depend on Lake Chad, has housed the terrorist group Boko Haram for nearly two decades. By some accounts, terrorism insecurity is a greater problem than food insecurity in the area, with millions internally displaced (Climate Change News, 2019; Vivekananda, 2019). For this reason, we shall focus on Borno State in Northeast Nigeria.

As mentioned, our goals for studying sustainability of agrarian societies in the LCB are twofold: (I) to develop a comprehensive database of climate and agriculture variables for the LCB and its peoples, going back decades or more (as feasible), thanks to Bayesian reconstruction; (II) a macro-level analysis of this data to evaluate the connection between the region's agrarian societies and the lake and basin's environmental systems, including an analysis of human impact, a valuation of agricultural ecosystem services to local populations, and environmental sustainability of their activities, over the past many decades, with Bayesian statistical projections to 2100.

First goal objectives: curate, complete, and manage datasets.

a) Curate environmental data from remote-sensed databases, e.g. high-frequency precipitation over the entire Yobe river basin on a fine spatial grid back to 1983 (CHIRPS data); extrapolate at lower frequency from the 1980s to the 1950s by exploiting a connection between a water-balance model and known hydrology data shared by France's IRD collaborator J. Lemoalle.

b) Calibrate and validate these data and reconstructions from weather station data available from our Nigerian collaborator dating back to 1929.

c) Reconstruct levels of agricultural productivity and hydrography from proxy information in historical and archival documents going back to the late 19th century; use it to extrapolate climate reconstruction to the same period;

d) Through collaborations with village chiefs and elders in Borno state, conduct surveys of current farming, pasturing, and fishing methods, challenges, and their views of rural sustainability past and present; we will ensure a sufficient number of village surveys are taken to provide the possibility of obtaining statistically significant results.

Second goal objectives: study rural sustainability and LCB ecosystem services valuation.

We will build analytical and predictive models in the Bayesian framework, to reject or validate hypotheses including:

- (1) Is global climate change directly linked to Lake Chad's past and recent variations?
- (2) Is global climate change likely to increase the frequency of droughts and to impact agricultural productivity in the LCB through 2100?
- (3) Under future climate change and population growth scenarios, can the LCB's ecosystem services be predictively valued to 2100? Are current agrarian practices sustainable?
- (4) Are local farmers or pastoralists responsible for any adverse effects on Lake Chad?

Our mathematical methodology on gauging correlations of time series (Ernst et. al, 2017; Ernst et. al, 2021; Ernst et. al, 2022) will have important impact on these questions, particularly item (1) above: attribution of Lake Chad's variations to global climate change or other factors. Current probabilistic modeling in environmental sciences essentially never uses time-series' full probabilistic structure in attribution questions. Our work has now shown exactly how misleading this can be when using classical statistical tools, with severe misinterpretations for non-stationary phenomena such as those in the LCB. Drawing on this mathematically precise analysis, we will improve testing procedures. We thus expect to reject convincingly the notion in (1) above. These tools will also provide the finer care needed in evaluating the LCB's risk under future climate change in items (2) and (3). This part of the research has important geopolitical implications, particularly in light of the first ever international agreement on a "loss and damage" climate fund for "vulnerable countries" at the 27th Conference of the Parties last month in Sharm-el-Sheikh, Egypt (UNFCCC, 2022). See sections on International Collaboration, and on Added Value.

Item (4) is a critically important social justice question. Some academics and international authorities have attributed blame to rural populations for Lake Chad's perceived ills (e.g. Coe & Foley, 2001, United Nations University, 2009). Others (Lemoalle et al., 2012; Magrin 2016) have not drawn such conclusions from their hydrological modeling and data analysis. The preliminary analyses of Viens, 2019 and Ikpe & Viens, 2022 show that the opposite might be true: farmers and pastoralists in Borno state are probably not overirrigating or overgrazing, not placing undue burden on their environment, and are profiting from the lake's variations in unexpected ways. For example, when an average (or better) wet season is followed by an unusually pronounced dry season, this possibly opens millions of acres of sustainable recessional pasturing.

Our ambitious program will access its full potential when we curate and improve the quality of the existing datasets on LCB agricultural sustainability. To this end, we shall employ hierarchical Bayesian machine learning, a probabilistic modeling and statistical extrapolation technique (for its utilization in agricultural economics, see, e.g., Baldos et al.). This Bayesian toolset has demonstrably improved statistical power over classical statistics, particularly with low-quality or limited data (Wang et al., 2019), and places uncertainty quantification on firm principled ground. Bayesian reconstructions and extrapolations of yearly rainfall in the LCB will be based on public remote-sensed data from US geological services, and proxy weather station data from our meteorology collaborator dating back to 1929. Historical and current environmental and land-use data in Borno state, some coming from our stakeholder surveys, some from UK and French colonial archives back to the 1880s, will help refine analysis of the LCB's ecosystem services and human environmental impact.

Plan of Action

Please indicate here a clear timetable for your research programme: