NSF-PIRE
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Table of Contents

Project Background

Partnerships for International Research and Education (PIRE) is a program funded by the National Science Foundation (NSF) to promote innovative international projects that enhance the welfare of global citizens through science, research and education. The Water and Food Security PIRE project seeks to understand how the relationships between scientists, farmers, water managers and other authorities influence the production, dissemination, and outcome of new scientific knowledge. Drawing on strong collaborations with partners in Ethiopia, we are introducing improved forecast products in six field sites in the Blue Nile Basin, Ethiopia, while observing the social interactions that surround this transnational scientific intervention. The Blue Nile Basin (BNB) contributes ~65% of the Nile flow and its water management decisions deeply influence all of East Africa. It has the physical resources to drive regional economic growth through irrigated agriculture and hydropower development, but its vulnerability to exceptional hydrologic variability and sensitivity to regional and global climate change have limited this development. We hypothesize that although forecasts help mitigate risk, political-institutional constraints may impede the development and transfer of scientific knowledge to manage risk. To test this hypothesis, we developed a novel field experiment that identify key sources of variation in hydroecological vulnerability (rain-fed versus irrigated agriculture) and in political-institutional vulnerabilities: “open” communities that encourage voice and trust versus “closed” communities that do not as well as highly institutionalized (hydropower), moderately institutionalized (irrigated), and minimally institutionalized (rain-fed) sites. By capturing both hydro-ecological and political-institutional variation, we are able to test competing models of science: a “pure science” model (communities mostly vulnerable to climate variability benefit most from forecasts), institutional model (more institutionalized communities implement forecasts at higher rates), and political-institutional model (open communities will exhibit greater benefits than closed communities).

Our objectives are to: (i) improve seasonal hydrologic and crop yield forecasts at scales relevant to farmers and water managers; (ii) identify and reduce barriers to their effective dissemination and uptake; and (iii) train a new generation of global experts who recognize both the political-institutional and hydro-ecological dimensions of food-energy-water security problems, collaborate successfully with international partners, and communicate fairly and effectively with stakeholders from disparate backgrounds.

Ultimately, we seek to develop a political-institutional model of science that links sociological and engineering methods in a people-centered approach to the human-climate-water-agricultural nexus.

Executive Summary

The third annual Water and Food Security PIRE Annual Meeting took place on November 21-22, 2019 at the Innovation Partnership Building at the University of Connecticut, Storrs, CT. The meeting was attended by partners from UConn, University of Wisconsin, Oklahoma University, and IFPRI. After the first round of forecast dissemination earlier in the year, the group had a great deal to celebrate, discuss, and plan. Day 1 of the meeting began with a welcome from PI Manos Anagnostou, and an update on overall project progress. It continued with presentations of findings from the social science, modeling, economics, forecasting, and outreach teams. Each team's presentation was followed by robust group discussions. Day 2 began with concurrent PI and graduate student brownbag meetings, allowing each group an informal venue to share successes, ask questions, and generate ideas for collaboration for the upcoming year. The remainder of the day was fully committed to group discussion. The first full group discussion focused on forecast dissemination, while the second focused on practical and ethical considerations for data sharing. This was followed by a series of small group roundtable discussions, focusing on interdisciplinary approaches to forecast dissemination, improved water management to alleviate social conflict, and Crop Yield Forecasting Using Analog and Statistical Approaches. The meeting ended with a full group discussion on potential interdisciplinary publications. Overall, it was a successful meeting, with a significant time devoted to forecast communication and dissemination, in preparation for the release of upcoming forecasts.

November 21, 2019 - Presentations

Day 1 of the meeting was devoted to presentations. Graduate students from the social science, modeling, economics, forecasting, and outreach teams presented their findings. Much of the data was collected during field trips to Ethiopia during the spring and summer of 2019. Full presentations are available by clicking titles below.

Social Science Presentations

Elizabeth Holzer shared an overview of the social science data collection so far. She shared the various types of data the social science team has collected, from "simple" to "complex." Simple data consists of household surveys and village and kebele-level interviews, while complex data consists of ethnographic observations and qualitative interviews. She shared the utility and analytical potential of each type of data.

Ezana Atsbeha shared findings from his fieldwork surrounding irrigation management. Specifically, irrigation management is complicated due to uncertainty around weather, sedimentation, and infiltration; institutional issues, such as access to water sources and maintenance of irrigation structures; and complex farm practices and production issues.

Selam Negatu and Kristen Kirksey presented on technology adoption in Dangishta kebele, with a focus on a tractor. Their findings surround dissemination, local considerations for access and use, and future opportunities. Dissemination takes place through sharing of experiences from other areas, observing improved crop outputs, and extension agents. Local considerations of farmers include timing, topography, and village-level coordination. In the future, farmers and extension agents hope for increased access to tractors through institutionalization.

Hawolti Curry's research focuses on how relationships between scientists, farmers, water managers and authorities influence production, dissemination, and outcomes of new scientific knowledge. She shared data from ethnographic research at ABA.

Berihun Adugna gave a comprehensive review of findings from the household survey, including descriptive statistics, irrigation calendar, primary crops, and farmers' sources of hydro climatic information. The team ultimately surveyed 1856 households in the experimental and control communities. The majority of heads of household were men (90%), illiterate (59%), and married (89%). Agricultural activities are typically carried out by men. Most farmers receive hydro-climatic forecast information from other farmers, followed by agricultural experts. Seventy-three percent of households believe they are completely free to make farm decisions. In rain-fed

communities, there is one primary planting season starting in May. In irrigated communities, there are two seasons, starting in November and February. For all households, the primary crop is maize, followed by finger millet. After sharing primary findings, Berihun shared next steps for data cleanup and analysis.

Modeling Presentations

The modelling presentations from UConn team were followed in this order - first, Rezaul Haider presented updates on downloading and post-processing of weather forecast data; then Rehenuma Lazin presented on progress with hydrological model development (CREST); Fahad Khan Khadim provided insights on the groundwater model development; and last, Meijian Yang presented his works on the crop yield model development.

The key aspects of the weather forecast post processing works were the bias correction and downscaling. For the wet season, the spatial bias correction for temperature and temporal bias correction for precipitation produced major improvements when compared with GDAS and IMERG data as references, respectively. For the dry season, precipitation bias correction was avoided since the amount was insignificant. Overall, based on the 32 members of the forecast, the 5th, 50th and 95th percentile members were chosen to simulate the seasonal forecasts later on by the impact models.

Rehenuma presented progress on CREST - a calibrated hydrological model. The model is validated with gaged streamflow data in Eldiem, Kessie, and Gilgel and performs well. Also, the model simulated evapotranspiration (ET) matches very well with GLIM ET. For the forecast, CREST was simulated using CFS data for the three members (5th, 50th, 95th percentile) and in the wet season, the pre-season soil moisture (SM) data was passed on to the crop model. For the dry season, CREST SM was not used. Instead, CREST only produced infiltration and streamflow to provide inputs to the groundwater model.

The major update from Fahad's work is the calibration of the local groundwater models in Koga and Quashni, the two irrigated sites where dry season forecast was provided. The local groundwater models are calibrated with citizen science data, to produce three output variables (head, SM and ET). The SM produced by the model validates with citizen

science TDR measurements very well as the model includes irrigation. Hence, it was used in dry season forecast simulation.

The crop yield model takes pre-season soil moisture from either CREST (wet season) or groundwater model (dry season) and analogue years based on total seasonal precipitation from the University of Wisconsin's team. Based on this data, five SM categories were conceptualized as being extremely dry (10%), dry (25%), normal (50%), wet (75%), extremely wet (90%). Meijian provided results on crop yields which takes weather data from GDAS/ ECMWF and IMERG/ MSWEP, plus the local planting dates and practices available from ethnographic surveys. Overall, in both dry and wet seasons, forecast yield patterns were normal or above normal.

Economics and ABM Presentations

In this session, Liangzhi You from IFPRI presented progress on the Economic Modelling, which was followed by Sardorbek Musayev's presentation on Agent Based Modelling (ABM). Liang discussed the economic values of climate modelling and discussed the method adopted in PIRE. He also presented some reviews on previous research which focused on how an improved forecast can benefit the economy of a community. After sociological experiments and surveys, and ABM modelling is finished the economic model will be used for specific results. The new model will not only be used in PIRE but also in IFPRI's Ethiopia Strategy Support Program in their analysis, e.g. the impact of irrigation expansion.

Sardor presented the developments with his ABM model and discussed the key concepts and methods. Once the ethnographic data collection is complete, he will calibrate the model focusing on the specific communities. Furthermore, he will set up a baseline scenario based on survey results and conduct experiments based on varying variables after the ABM is calibrated. The model will be used to predict farmers' decisions on agricultural productivity.

Forecasting Presentations

Ezana presented on the local response and challenges with forecast dissemination. Overall, the bulletins were accepted well by local communities. However, the farmers, other than those trained by the research team, did not hear about the forecast. He expressed the need to work with regional and woreda agriculture bureaus to embed forecast dissemination in day-to-day extension work.

Jonathan Lala presented his progress with the statistical forecasting of the kiremt (wet season) onset in Koga. His work inferred that the April 1 window method for onset balances skill and lead time. There was a trend of increasingly early onset, with no trend in seasonal precipitation. While carrying out the dynamic model comparison (ECMWF), similar skill with finer spatial resolution (0.05° vs. 0.25°) and shorter lead time (~1 month vs. 3-4 months) was found.

Sarah Alexander presented her works on predicting seasonal precipitation, the reservoir volume and also the journey through the forecast bulletin development. The precipitation prediction is made from statistical analysis, which is used in a water budget analysis to predict Koga reservoir volume. The key question was presented was when are reservoir volume predictions valuable to ABA, farmer cooperatives, and others. At the end of the forecast bulletin development presentation, there was an open discussion providing feedback on how the bulletin could be further improved next season. The general message was that information still needs to be a bit more farmer friendly. Specifically, the details on soil moisture, the estimates of reservoir levels and release amounts is still hard to interpret from a farmer's perspective. This needs a lot of brainstorming in the coming weeks.

The session ended with Emmanouil Anagnostou's presentation on model integration. The presentation was very concise and talked about how each model is feeding the next in the chain. The process starts with the weather forecasting data downloading and processing, which is passed on to the CREST model, the output of which either directly goes in the crop yield model (wet season) or feeds the groundwater model (dry season). The groundwater model then feeds the crop yield model in the dry season. The crop yield model also takes into account the analogue years based on total precipitation.

Outreach Presentations

The outreach session included two presentations, the first one from Fahad Khan Khadim, who presented the progress on citizen science initiative, and the second one from Teshome Lemma Yami from Oklahoma University, who presented progress on the e-PING and database development. The citizen science was previously focusing on the four communities, however in the new extension more focus is provided in the irrigated sites to collect data on irrigation flow. The e-PING development is in the final stages now and is expected to conclude within the next two months.

November 22, 2019 - Discussions

Day 2 of the Annual Meeting was devoted to discussions. It was an excellent opportunity to expand upon findings presented during Day 1 of the meeting, ask questions, and propose directions for further research. In a large project that spans multiple countries, institutions, and disciplines, these discussions are invaluable.

PI Meeting

The Principal Investigator meeting focused on the sustainability of the project beyond the project period. They discussed the idea of extending the project by one year, as well as a number of subsequent projects that can build on the work started by the Water and Food Security PIRE. The PIs are committed to building sustainability by engaging the Ethiopian team in a more extensive way. They discussed the possibility of transferring modeling work to the Ethiopia team, potentially Bahir Dar University. They also considered enhancing the contribution of Ethiopian social scientists by engaging them in forecast communication.

Graduate Student Brownbag

The brownbag was attended by all PIRE graduate students and one undergraduate student. First, Sardor Musayev, Environmental Engineering graduate student, shared findings from his Agent Based Modeling project, which attempts to identify key information exchange agents and understand the key information flow pathways through which the seasonal forecast might be disseminated. After sharing his project, he answered questions and gave an informal demonstration and lesson on ABM. After Sardor's presentation, Ezana Atsbeha, Sociology graduate student, expanded upon his presentation from the previous day, and shared his proposed dissertation work. Because the graduate students are typically dispersed around the country and around the world, it was an excellent opportunity to meet face to face, have informal conversations, and share our research with colleagues across disciplines.

Full Group Discussion 1: Forecast Dissemination - Reflections and Improvements (moderated by Sarah Alexander)

Sarah Alexander, a Wisconsin engineering graduate student, presented a concise timeline of the creation of the 2019 rainy season forecast, as well as the challenges and opportunities that arose during the process of dissemination. She then opened the floor to comments and suggestions for future forecast dissemination. The primary area of improvement soil moisture

forecast. There were also brief discussions of the calendar, recommendation section, as well as seed selection.

Soil moisture:
Members of the social science team reported that the way that soil moisture was presented on the forecast was not actionable. However, there are local ways that farmers understand and soil moisture and act upon this information. Ezana Atsbeha, a UConn social science graduate student, explained that many farmers use the depth of the soil in relation to an oxen's foot or a plow to determine a gradient of types of soil, soil moisture, and subsequently, planting times. Meijian Yang, UConn engineering graduate student, will explore the possibility of validating the traditional methods, and determining their relationship to crop yield. All agreed that this is an interesting direction for a future project. The social science team confirmed that we have both qualitative data and survey data regarding planting times that can contribute to this project.

The team agreed that for this year's forecast, we will remove soil moisture from the forecast bulletin. We will keep the possibility of adding it back if we have a more actionable way to present it. If it doesn't map onto crop yield, then we should cut out discussion of soil moisture in the forecast. The group then began a discussion of what to replace the soil moisture with on the bulletin. The social science team indicated that farmers had requested information on finger millet and teff crop yields, as well as dry spells during the rainy season and cessation of the rainy season. The Wisconsin team reported that the cessation and within-season variation information is not yet reliable enough. We will continue to explore information useful to farmers that can replace soil moisture on the bulletin.

The calendar:
Ezana informed the team that we may need to re-think the presentation of probable days for rainy season onset. In the rural Ethiopian context, time is typically not organized in this way. A simpler approach would be to say "The most likely period of onset is…" Extra information could cause confusion. The bulletin should retain its visual nature, however, to continue drawing interest.

Recommendations section:
Liz suggested that we change the word Recommendations to Summary on the last panel of the forecast bulletin. Sarah explained that the word Recommendations had been chosen because in early iterations of the forecast, actionable items were to be included. Liz added that in earlier iterations, the PIs were more focused on measuring impact. Now, however, we should be more humble and focus on best practices instead.

Seed selection:
Manos explained that we get some pressure from farmers to get an accurate January/February forecast so that they can secure the seeds that they want. Ezana added, however, that as of now, there does not seem to be much elasticity in types of seeds that are available for farmers to plant, so we shouldn't worry too much about that. The major seed we should look at is maize, as there are 2 or 3 varieties, and dagussa, which has 2 major types. Teff, on the other

hand, is a household heirloom seed. So far, we have seen that seed choices don't change much based on weather, but there is variation from kebele to kebele. He added that we should look more into elasticity of seed selection. Liz added that we should work with NMA and seed distributors on this.

Full Group Discussion 2: Practical and Ethical Considerations for Surveys and Ethnographic Data Sharing (Moderator Holzer)

Liz began with a statement on the limitations of ethnographic data and interviews. She explained to the group that much of this type of data is internalized by the researcher and doesn't make it into field notes, which can lead to misunderstandings of data. Typically for ethnographic data, the only person who uses field notes is the actual researcher. In our case it's different because we want to share data.

Therefore, she has two recommendations:

1. If you want to write a paper with ethnographic data, you can request the data and code it based on specific quotes, so that it can always be cross-referenced. Then, you can go to the person who collected the data and ask if they can write a paper with you. We should always be co-authoring papers with ethnographers. For survey, always co-authoring with Berihun and Boris, and also Ethiopia collaborators.
2. Do not share data with anyone outside of the PIRE team for the next 3 years. Right now, the data is owned by the PIs. When you think about authorship, it's always important to include people who collected the data. We need to formally incorporate as authors people on the ground in Ethiopia when appropriate.

For household surveys, we have already cleaned that to make intelligible to all of us. It needs to be standardized at household level and kebele level. We need people to help with this process to have the data ready as quickly as possible. We should incorporate undergrads into this process. Some of the household and kebele level data will be ready for January, while the timeline for the rest is unclear. Village level survey data is available now, which includes all info about weather and demographics. To access, you have to request via email from Liz.

Roundtables

In advance of the meeting, we solicited titles of joint papers under development for roundtable discussions. We spent about 2 hours rotating around the tables, and sharing, elaborating, and getting feedback on joint papers. First authors moderated the discussions, and summaries of each discussion are below.

Interdisciplinary Approach to Seasonal Forecast Communication (Moderator Sarah Alexander)

The team led by Sarah discussed a joint paper that has already been drafted that details our multi-method approach to forecast communication in Ethiopia, supported by qualitative field notes and interviews. In general, those in the breakout sessions seemed to concur with the current outline for the publication. However, there were many fruitful discussion points and

points that may deserve clarification. A few additional points that were raised had to do with the understanding of the bulletin, pointing out that understanding was not always immediate, but rather occurred throughout the process of the conversations, trainings, etc. Further, we discussed trust and mis-trust in the agricultural extension system. More trust may exist between the government designated model farmers and agricultural extension experts, and some mistrust between the model farmers and other farmers was observed. Thus, we want to be careful to not replicate existing inequalities in the agricultural system through our communication approach. This point has clear implications for the 2020 communication, where we may wish to try and reach outside this government defined agricultural extension network to other farmers, make announcements at church, etc.

A couple of different ways to structure the paper were raised. First, we discuss descriptive versus analytic themes and it was suggested that the field notes could be used to support a comparison of different forms of understanding through each of these themes. Another suggestion was to build the story from the engineering perspective (with no interaction with the end-user), and then illuminate how traditional engineering thinking gets complicated by this social interaction. In other words, the interplay between physical science/engineering thinking and social understandings has implications for the best practice of communication. In the end, consensus was that there are many different angles to approach these topics and multiple joint publications may be warranted.

Improved Water Management to Alleviate Social Conflicts (Moderator Fahad Khadim)

The idea of this particular research was to bridge key local water management applications with problems associated within the multiple aspects of social science. This roundtable session was moderated by Fahad Khan Khadim, a PhD student working with assessment of groundwater resources in the Upper Blue Nile, with significant emphasis in the local communities. One of his current research involves exploring the different irrigation and water management cases and producing soil moisture and water allocation profiles by simulating the groundwater model. The preliminary insight for this session was to tie the consequences of different water management techniques with some of the existing societal problems reported during the key informant interviews or the detailed household surveys. In the process, the idea of linking social conflicts with water management applications was envisaged. However, as the roundtable session progressed, it was clear that this argument is hard to justify because first, there is no detailed data on local social conflicts reported by the surveys, and second, whether such conflicts would be clearly related to water management applications and not some other factors, is difficult to assess. Various participants provided their valuable opinions during the discussion. At one point, it was mentioned that while the household surveys, the local people in Koga and Gaita were asked whether they feel that the water provided to them during the irrigation season is sufficient. They were also asked if they consider this form and quantity of the shared water as ‘fair’. From that point, the research idea was modified to some extent, and a new idea was proposed to assess whether the model simulated spatial distribution of irrigation water availability and soil moisture profiles correlate with the farmers’ perception of fairness, and if so, possibly explore the salient methods that could potentially improve this idea of social fairness.

Crop Yield Forecasting Using Analog and Statistical Approaches (Moderator Meijian Yang)

This paper will focus on the seasonal yield forecast of cereal crops in the 4 selected sites using analog and statistical approaches, and the comparison of their performances. The analog approach is developed based on the selection of climate variable(s) at various time ranges with the highest analog skills in predicting crop yield. As for statistical approach, we'll start with linear statistical model and perhaps make further exploration of other methods. Moreover, long-term crop yield forecast based on the shift of distributions between past and future climates could also be included.

List of Potential Publications

During the final session of the annual meeting, participants proposed ideas for collaborative research projects. After two days of informative presentations and productive discussions, participants came up with an extensive list of ideas, detailed below.

Topic	**Lead author**	**Other collaborators**	**Timeframe**
Forecast communication: best practices from 2019 [consider subdividing this paper]	Sarah	Kristen, Selam, Ezana. Paul, Zoi, Semu and Manos (how physical scientists changed their understandings) Guiling (co-production part); Dominique	January 2020
Fairness, Sufficiency and Soil Moisture	Fahad	Berihun, Ezana, Liz, Rehenuma, Manos	September 2020
Fairness, Sufficiency, Social Moisture and Water Management	Fahad	Ezana, Berihun, Liz, Rehenuma, Manos	December 2020
Integrating different measures of soil moisture: self-assessment, citizen science, plough, ox, self-assessment	Liz	Guiling, Meijian, Rehenuma, Fahad, Manos	May 2020
Types of certitude and uncertainty in weather and climate forecasting; tolerance for risk as part of this paper?? (e.g. of clouds and clothes drying versus crop)	Liz	Ezana, Sarah, Mamaru, Kristen and Selam, maybe Manos?	
Forecasting crop yield with analog and statistical methods	Meijian	Jonathan and UW crew, Guiling, Manos, Berihun, Liang	January 2020
Bias correction, crop yield, streamflow simulation	Razuel	Rehenuma, Meijian, Manos, Guiling, Fahad, Mal	July 2020

Translating “climate change” “weather” “climate” and consequences for forecasting	Liz	Liz, Ezana, Kristen, Selam, Sarah, Paul, Dominique, Hawolti, Mamaru??; Sardor, Jon, Berihun, Manos	September 2021
Incorporating technology into scenarios, crop forecasting	Meijian	Ezana, Guiling, Manos, Liang	November 2020
Technological Adoption and Social Relationship: The case of the tractor	Selam and Kristen	Ezana	
Modeling more complicated agricultural practices in Irrigation management; making decisions about which complexities to model	Ezana	Manos (maybe Fahad, Paul, Guiling or Rezaul?)	October 2021
Production efficiency of maize	Berihun	Boris	July 2020
Community participation and social stratification (regression models)	Liz (organizational)	Liz, Kristen, Selam, Hawolti (maybe Berihun and Boris)	December 2020
Voice and social stratification (regression)	Liz (organizational)	Liz, Kristen, Selam, Hawolti (maybe Berihun and Boris)	January 2020
What makes a good day in Kudmi? Everyday life in small-scale agricultural community	Ezana and Liz	Kristen, Selam	March 2020
Challenges and opportunities of interdisciplinary collaboration: The case of …	Kristen	Sarah, Selam	Working on it next Fall 2020
Rainy season timing in crop yield modeling	Jonathan	Meijian, Guiling, Paul	April 2020
What is “onset?”	Jonathan	Ezana, Meijian, Guiling, Paul	December 2020
Economic modeling: impact of seasonal forecasts; sensitivity models	Jonathan	Liang, Paul, Berihun, Boris	
Machine learning and household survey data? [AI]	Manos’s student	Liz, Manos	After statistical models have been run
Dry season forecast framework—how we made the forecast	Fahad	Zoi, Manos, Meijian, Razeul, Rehenuma and everyone else involved	
Accuracy of our forecasts	Zoi	All the people who put together the forecasts	

Conclusion

Overall the annual meeting was a success. We found great progress on data collection from all disciplines, especially surrounding forecast development and dissemination. We are proud of our hydrologists and scientists' collaborative work to develop the forecasts, as well as our social scientists' efforts to develop new ways of discussing probability with water managers and farmers. For the next two years of the Water and Food Security PIRE Project, we aim to collect data on impact, specifically measuring any changes in agricultural decision-making in years that are not normal. In future years, we hope to continue building relationships among partners, work on project sustainability, and disseminate results. We plan to hold the 2020 Annual Meeting at a different US partner institution, and pending the political situation in Ethiopia, we plan to reschedule the project summer school at Bahir Dar University. Finally, near the end of the project, we will organize a policy workshop with our partners and stakeholders in Ethiopia. We look forward to what's to come!