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Citizen Science and Public Perceptions under A Changing Climate: an Empirical Study in The Upper Blue Nile, Ethiopia

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Abstract

This paper presents a citizen science approach implemented in the Upper Blue Nile (UBN) region of Ethiopia to study the farmers' perceptions towards adequacy of the quantity of the provided water and the fairness of the irrigation distribution system. The paper also includes preliminary Machine Learning (ML) based results on finding the optimal initial cultivation time in Ethiopia as a means to alleviate heat-induced crop losses in a warmer climate.

Keywords: Cultivation; Machine Learning; Climate Change; Citizen Science; Public Perceptions; GW-based Irrigation, Soil Moisture, Weather Forecasting, Post Harvest Management, Neural Network and Support Vector Machine

Introduction

Agricultural production sustains a large part of the population in sub-Saharan Africa, relying heavily on rainfed agriculture and partly on reservoir-based irrigation schemes. Climate change may decrease the Ethiopian maize yield by 35% (from ~1400 down to ~900 kg/ha) by late century. This study evaluated the effects of a citizen science approach implemented in Upper Blue Nile (UBN) region of Ethiopia in shaping the farmers' perceptions towards adequacy of the quantity of the provided water and the fairness of the irrigation distribution system. This paper also presents some preliminary results on optimizing the initial cultivation time in Ethiopia as a means to alleviate heat-induced crop losses in a warmer climate using Machine Learning (ML) models.

Citizen science initiatives have been on the forefront of most informational campaigns either regarding the development of an infrastructure project or applying a new policy that involves the public in scientific research [1], given their ability to overcome social resistance and advance the social acceptance towards innovation. Moreover, active citizen participation has the potential to build the notion of common ownership to infrastructure projects and thus assist to a smoother development and construction phase. Towards this end, in this article we examined the effect of citizen science projects on the formation of public perceptions, regarding a large irrigation management project.

Methodology

During the PIRE project "Food and Water Security in Ethiopia" a large water management project in the Upper Blue Nile, a groundwater model (GW) was developed to assess the potential of GW-based irrigation to address water stress situations and eventually improve irrigation efficacy [2]. Results from a companion study employing the Decision Support System for Agrotechnology Transfer (DSSAT) model are used to analyze the response of crop yield to projected climate changes.

The project was coupled with a citizen science project where Ethiopian farmers were educated on the notions of soil moisture, weather forecasting and irrigation management schemes to improve crop production. In parallel, as part of the project, Ethiopian farmers from 8 villages (kebeles in Amharic, the primary Ethiopian language) participated in a survey with the goal to determine the parameters that drive social perceptions towards fairness and adequacy of the irrigation management scheme. The survey was organized in several sections, including data on demographics, community participation and the role to the decision making of the community, land, agricultural productions and post-harvest management, economics of the household situation and weather forecasts.

Harnessing the analytical power of machine learning models in extracting patterns from data, we exploited the informational content of a survey in two irrigated communities of Ethiopia, namely, the Koga Reservoir and the Quashni River irrigation project areas in determining the factors that shape public perceptions towards water. Based on an extended socioeconomic questionnaire and forecasts from a calibrated MODFLOW-NWT GW model, we investigated the significance of the level of precipitation, freedom to express one's opinion, and the participation of the local community in irrigation management. Combining the survey data with hydrological data on precipitation and soil moisture, we accessed the power of machine learning analytics to pinpoint the parameters that shape public perceptions. After preprocessing the available data for missing values and classifying them to three distinct types of years according to precipitation intensity (dry, normal, wet year) we evaluated the forecasting ability of a Random Forest, an XGBoost, a Logit, a Neural Network and a Support Vector Machine model to accurately predict public perceptions on fairness and adequacy of the irrigation system based on the informational content of all available parameters; social and hydrological.

Data

The most important variables detected according to the most accurate forecasting models are as follows:

Dependent variable: Quantity or fairness (normal year) [*italics* in fairness, **bold** both]:

Significant variables:

i. Average daily wage in village or **kebele**

ii. Average cultivating cost in kebele

iii. Type of community (Open – Closed community)

Weather forecast

i. Family consumption needs determines the crop to plant

ii. Planting month and week

iii. Source of weather forecasts are Farmer cooperative members

iv. Rain fall in 2018 is considered much worse than normal year

v. Number of tilling the land during a normal year

vi. Number of timads of land cultivated in normal year

vii. Planted regular crop earlier than usual in normal period.

viii. During normal period grew more cash crops

Irrigation system

i. Source of Irrigation water is stream/river by gravity

ii. Source of Irrigation water is s*tream/river* by li*f*t system/ other

iii. Irrigation system used is motorized pump.

iv. Irrigation by drip irrigation plastic tube

Participation to local organizations and treatment from local authorities in terms of freedom

i. In the last year I have sought resources from a NGO

ii. Degree of freedom in criticizing public official

Owner of the house of residence (j07_1)

Precipitation(normal year- 2017)

Dependent variable: Quantity or fairness (dry year) [*italics* in fairness, bold both]:

Significant variables:

Type of community (Open – Closed community)

i. Average daily wage in *village,* kebele or reg*ion(woreda)*

ii. Average cultivating cost in ke*bele* or village

iii. Age of the head of the household

iv. Precipitation(dry year- 2015)

Weather forecast

i. Source of weather forecasts are "Farmer cooperative members

ii. Source of weather forecasts are "Local newspaper"

Participation to local organizations and treatment from local authorities in terms of freedom

i. Issue of concern are agricultural inputs

ii. Issue of concern is justice/administration

iii. Fair treatment from police/militia

iv. Fair t*reatment from woreda officials*

v. Fair treatment from kebele *officials*

vi. In my community I am free to say *what I* think.

Irrigation System

i. Source of Irrigation water is stream/river by lift system

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ii. *Use traditional irrigation system constructed by farmers*

iii. *Irrigation water is used during dry season only*

iv. Irrigation by drip irrigation plastic tube

Owner of the house of residence (J07_1)

Precipitation(dry year- 2015)

Dependent variable: Quantity or fairness (wet year) [*italics* in fairness, **bold** both]:

Significant variables:

i. Average daily wage in village, kebele or r**eg**i**on (wo**r**e**d**a)**

ii. Average cultivating cost in kebele *woreda*

iii. Age of the head of the household

iv. category of the community (open Cat)

v. Precipitation(wet year- 2018)

Weather forecast

i. *Source of weather forecast* is *Church priest*

ii. *Source of weather forecast* is *Woreda/kebele Ag expert*s

iii. *Source of weather forecast* is *Irrigat*ion project *expert*s

iv. Source of weather forecasts is Local newspaper

v. *Rainfall* in *2018* is *much worse* than *a* normal *year*

vi. *Type of crop planted year*-to-*year* in *Meher*

vii. Number of timads cultivated

viii. Number of times tilled land

ix. *During wet year cult*ivated more cash crops

Participation to local organizations and treatment from local authorities in terms of freedom

i. Treatment from kebele officials

ii. In my community I am free to say what I think

iii. In my community I am free to make farm related decision for my own household

Irrigation System

i. Source of Irrigation water is stream/river by lift system

ii. Irrigation method used is motorized pump

iii. **Irrigat**ion water is used duri**ng** dry season only

iv. Irrigation by drip irrigation plastic tube

v. *Precipitation* (wet year- *2018)*

Results

Figure 1 presents results from a GP ML model that shows the spatial variation of the optimal month for initial cultivation time in Ethiopia during a wet year. It should be noted that June is the traditional initial cultivation time in Ethiopia. The green-to-blue colors traversing a NW-SE zone in Ethiopia indicate that during a wet year, these lands could easily sustain a delay in cultivation time up to two to four months.

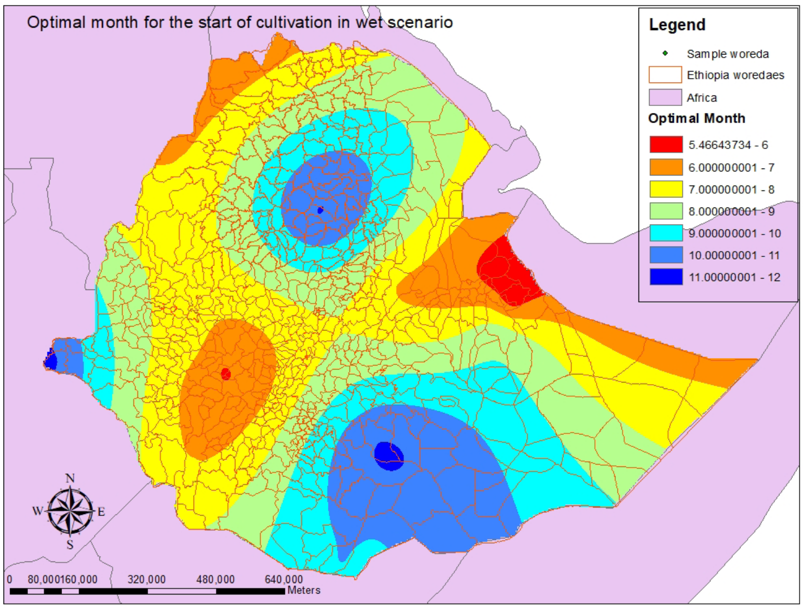

Figure 1: Spatial variation of the optimal month for initial cultivation time in Ethiopia during a wet year.

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Figure 2 shows the spatial variation of the projected improvement in the crop yield as a result of starting cultivation at the optimal month as compared to starting cultivation in June. By initiating cultivation during the optimal month improvement in crop yield ranging from 670 to 1200 kg/ha can be realized in the NW-SE corridor.

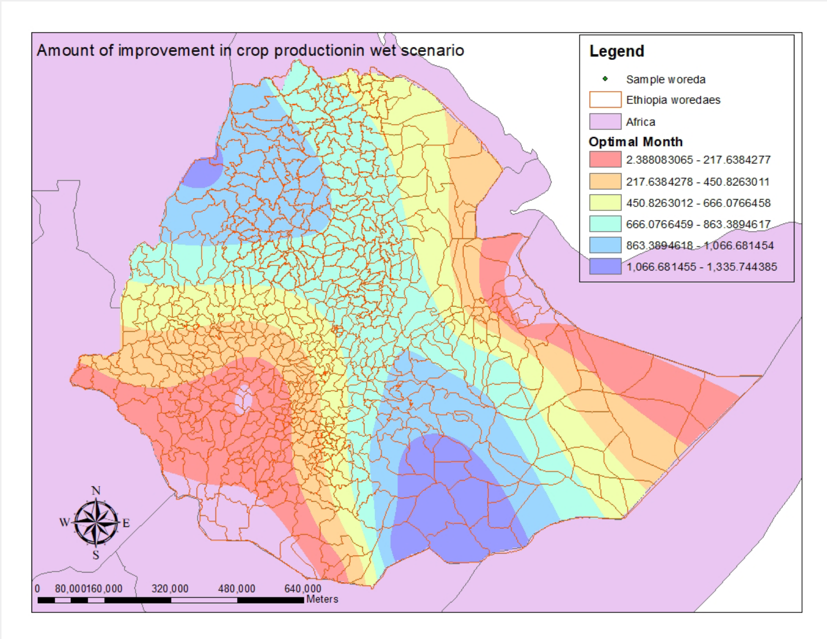

Figure 2: Crop yield improvement as a result of starting cultivation at the optimal month as compared to starting cultivation in June.

Conclusion

Our empirical findings suggest that although the scope of the forecasting exercises is the irrigation system, hydrological variables appear to be significant only episodically. In contrast, the most common variables driving the forecasting performance of all models were cultivating cost, the average wage in the village or the region (woreda in Amharic), and whether the community incorporate stake-holders in the decision-making process and reach decisions transparently [3]. Moreover, treatment of public officials and the police towards farmers impacted significantly the perception of fairness towards the irrigation management system. In fact, even precipitation was not found to be affecting public perceptions towards fairness and that even during a dry year. Only when the question raised was on the quantity of water received did precipitation appeared among the significant factors and that only marginally.

Overall, citizen science projects seem to be impacting only slightly the public perceptions, suggesting the need for a broader examination of the targeted groups, since less educated groups, as the ones included in this study, fail to incorporate and/or appreciate the importance of the initiative.

Socioeconomic rather than hydrological variables appear to be drivers in agricultural decisions about crop selection and planting period, underscoring those factors as potential criteria in drawing successful agricultural policies for crop yield optimization.

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