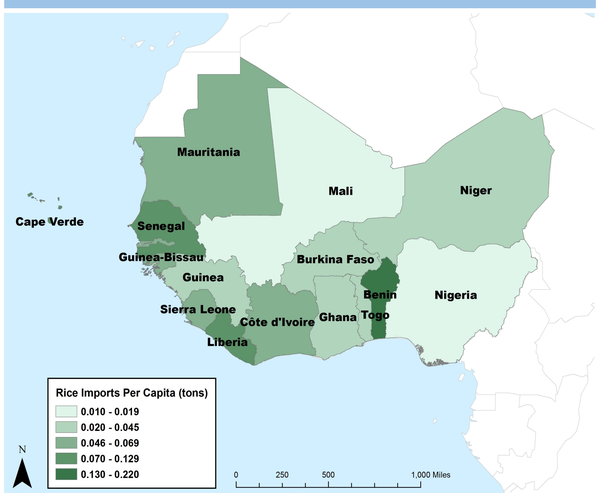
RICE AT RISK: HOW CLIMATE AND SOIL CONDITIONS IMPACT FOOD SECURITY IN WEST AFRICA

Introduction

Global climate change has had a myriad of negative impacts on traditional agriculture systems by exacerbating conditions in various agro-ecological zones, a phenomenon that often affects soil conditions, rainfall patterns and crop production. This project uses GIS to analyze risk of rice crop failure in West Africa through the analysis of several key environmental factors that stem from global climate change and contribute to declining yields in rain-fed rice production: precipitation variability, soil nutrient deficiency and aluminum contamination. These ecological constraints impact cultivation in nations with long cultural traditions of rice consumption. Paradoxically, nations with such rich histories in rice production have become net rice importers. This analysis demonstrates how the countries that are the most severely impacted by rice crop failure are the most reliant on the international rice market.

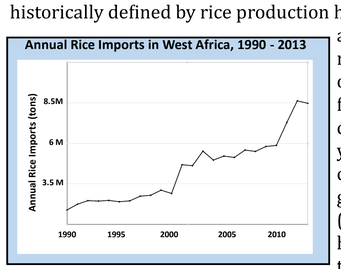
Area of Interest



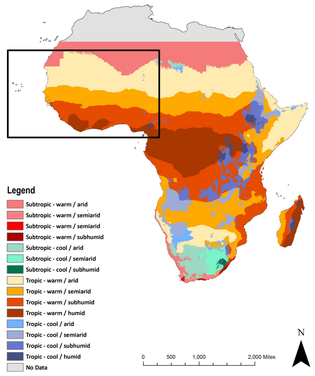
Background

The cultivation and consumption of rice has been an essential component of West African cultures for the last 3000 years. The region has a history of heavy rainfall and low lying floodplains conducive to rice agriculture. Over thousands of years the crop has assumed a sacred quality; it is deeply entrenched in West African economic, social and religious life. In the 15th century, European colonial policies in the region mandated a shift in the role of rice from a food crop for local subsistence to a cash crop for European consumption (1).

In the wake of Western economic imperialism, an area that was historically defined by rice production has seen a rise in urbanization and a decline in rural development. The shift to a cash economy has compromised the food sovereignty of West African nations; over the last 50 years, the region became increasingly dependent on the global market for rice imports (3). Though West Africa has high potential for rice cultivation, yields are consistently lower than those of the world's leading rice production regions in Southeast Asia. High marketing and production costs, coupled with low productivity, prevent local rice producers from competing with global market prices. In 2008, this situation was exacerbated by the global economic crisis, when world food prices tripled. As consumer purchasing power declined, so did retailer profits. As a result, food insecurity in urban areas increased (3). Governments have reacted to this crisis by lowering taxes on imports and supporting domestic production through investments in agriculture. However, growth in rice production remains lower than local demand. Even now, West Africa only produces enough rice to account for 60% of its consumption needs (3).



Agro-Ecological Zones (AEZ) in Sub-Saharan Africa



Agro-Ecological Zones in West Africa

Rice cultivation in West Africa spans 4 agro-ecological zones:

- **Tropic - warm/arid**
- **Tropic - warm/semiarid**
- **Tropic - warm/subhumid**
- **Tropic - warm/humid**

Climate change and rising temperatures cause a shift in AEZ across geography. Rice agricultural systems are most productive in specific climate ecologies, and are therefore very vulnerable to AEZ migration (2).

Growing Potential: Rain-Fed Rice

Upland rain-fed rice cultivation is the most extensive rice farming system in Africa, and is a key component of West African rice production (2). However, rain-fed rice ecosystems are especially vulnerable to climate threats. Three ecological factors that greatly impact rice yields are examined in this analysis:

Rainfall: precipitation is the only source of water for rain-fed rice, therefore high variation in rainfall can have a dramatic effect on yields.

Nutrient Capital: soils in rain-fed rice ecosystems are highly weathered with low nutrient-retention capacity—usually poor in nitrogen, phosphorus and sulfur.

Aluminum Toxicity: soil contaminated with aluminum can be toxic to crops, causing plant nutrient deficiency by fixing with phosphates in acidic soils.

Methods

First, raster data for rain-fed rice production, annual variation in rainfall, aluminum toxicity and low nutrient capital reserves was downloaded, projected to Africa Albers Equal Area Conic and clipped to the West Africa study area. Each raster layer was re-classified to a 5-class scheme that ranks the prevalence of each factor. Then, risk of rice crop failure was calculated by finding the sum of the four raster layers. Each layer was assigned a different weight in the calculation based on relative significance (contribution to low rice crop yields). The weights and unit of each factor are as follows:

RASTER	UNIT	WEIGHT
rain-fed rice production	metric tons	50%
variation in long-term annual rainfall	millimeters— median absolute deviation	25%
low nutrient capital reserves	percent of area affected by soil chemical constraints to agricultural production	12.5%
aluminum toxicity	percent of area affected by soil contaminated with aluminum	12.5%

Rain-fed rice production is given the highest weight as it is the cornerstone of the analysis. Rainfall is weighted twice as high as the soil components because it has the largest impact on rain-fed rice yields.

Limitations

Due to constraints on data availability, this project only examines 3 ecological factors impacting rain-fed rice yields. Other important spatial components to consider include: plant diseases, major pests, population pressures, and weed control.

Also, the resolution of rainfall variability is not to the same scale as the other factors due to the source of the raster data.

Lastly, in the interest of obtaining full data sets, economic and population statistics are only as recent as 2013.

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GIS 101, Spring 2016

Projection: Africa Albers Equal Area Conic

Data Source: HarvestChoice/IFPRI (2010-2015) ESRI (2010), FAOSTATs (2013)

References:

1. Davidson, Joanna. "Sacred Rice: Environmental Change and Structural Uncertainty in Rural West Africa." Lecture, Environmental Studies Lunch and Learn, Tufts University, MA, April 28, 2016.
2. Sant'Anna, R., and J.R. Oteng. *Rice Production in Africa: Current Situation and Issues.* Report. Vol. 48. Rome: FAO, 1999. FAO Corporate Document Repository. Accessed 28 April 2016.
3. *The 2008 Rice Crisis: Shock and New Challenges.* Report. Sahel and The West African Club Secretariat (SWAC/OECD). June 2011. Accessed 28 April 2016.

Image: farmlandgrab.org

Tufts

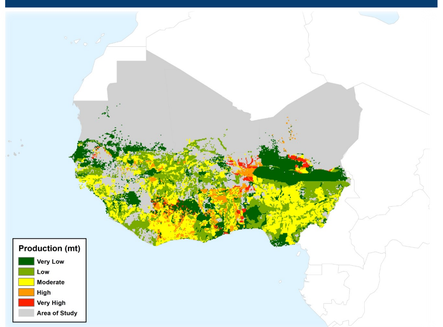
Results

The final map shows areas of West Africa with varying degrees of risk of rain-fed crop failure. Much of the area classified as moderate or high risk lies within the boundaries of West African countries with relatively high rice imports per capita. This spatial relationship shows how such economic hardship is exacerbated by climate conditions (soil contamination, low nutrient-retention and unpredictable rainfall patterns). Progress towards regional self-sufficiency is contingent on prioritizing sustainable rural development and implementing policies that help farmers face the agricultural challenges posed by global climate change. By improving the resiliency of domestic, rain-fed rice agriculture, West African nations can reduce economic dependency on the volatile global food market and increase regional food security.

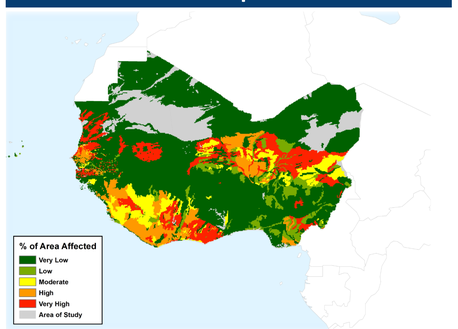
Image: African rice farmers work in a paddy in Gambella, 2014

Analysis Factors

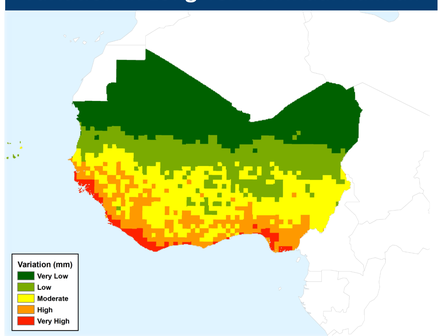
Rain-Fed Rice Production



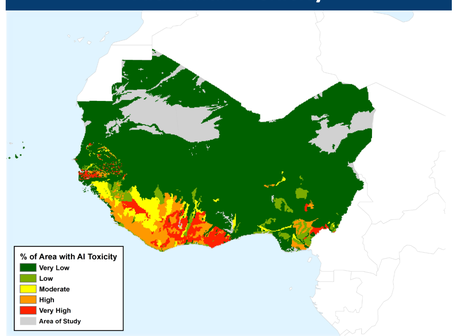
Low Nutrient Capital Reserves



Variation in Long-Term Annual Rainfall



Aluminum Toxicity



Risk of Rain-Fed Rice Crop Failure