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MEASURING AND MANAGING AGRICULTURAL IMPACTS ON WATER RESOURCES: A CASE STUDY OF THE PANGANI BASIN

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Changes in global agricultural prices impact world markets but also have significant effects at a local scale. Changes in local prices of a good can affect many aspects of agricultural production including resource consumption and allocation. This project considers the effects of a trade-induced increase in world rice prices on crop production and the subsequent rise in agricultural water demand. Specifically, the project presents a case study of the rice sector and water resources in the Pangani River Basin of Tanzania.

The Pangani Basin is currently experiencing water stress and resource conflicts brought on by competing water users, including agriculture, households, and hydroelectricity. By quantifying changes in water demand due to changes in world rice prices the project provides policy-relevant insights into the current allocation regime's adaptive capacity and offers alternative allocation mechanisms. The project concludes with a guide for policymakers that offers important lessons, considerations, and pitfalls associated with this type of analysis. This information will help the United Nations Environment Programme (UNEP) to incorporate the lessons learned from this project into future integrated assessment endeavors.

Figure 1. Rice farmers in Tanzania (Source: IFAD photo by Robert Grossman)

Trade Liberalization and Water Resources

Trade liberalization provides a means of increasing trade between nations. Even as markets become increasingly global, the effects of increased trade on local markets and the local environment have often been overlooked. These local effects can be significantly positive or negative. Trade liberalization of the agricultural sector has particularly large effects on a local scale due to the extent to which crops are grown on smallholder plots and the role agriculture plays in poverty alleviation. Water resources are an essential input for the production of agriculture and are particularly affected by changing demands through agricultural trade liberalization. However, little research has examined the impacts agricultural trade liberalization can have on water resources. This project provides a policy-relevant means of elucidating some of the effects of trade on local resources and explores mechanisms for solving the problem of water allocation. Worldwide 70% of fresh water resources are used for agriculture, while in Africa it is nearly 90% (*1*). This global trend underscores the important link between agriculture and water resources particularly in developing countries.

The Importance of Rice to Tanzania

About 80% of the work force in Tanzania is employed in agriculture. Rice was introduced in Tanzania between 1890-1920 and has become an important food staple for about 60% of the population. To meet growing demands, the total cultivated area for rice has increased substantially over the past several decades. Rice is one of the few irrigated crops in the Pangani Basin and the most water intensive. Rice is traditionally grown in river valleys using irrigation fed by springs and river diversion.

Rice consumption in Tanzania is estimated to be 232.7 kg per year per person (for comparison, the United States consumes approximately 11.3 kg per year per person) (*2*). The potential for increased rice production with the use of irrigation in the Pangani Basin is estimated at 150,000 Ha.

Advisors: Carol McAusland and Oran Young

The Current Situation in the Pangani

The Pangani River Basin is located in the North East of Tanzania and encompasses an area of 42,000 square kilometers. The Pangani River is fed by runoff from Mt. Kilimanjaro, the highest mountain in Africa. The climate in the basin varies considerably between the slopes of Mt. Meru and Mt. Kilimanjaro, which receive 1,200-2,000 mm of rainfall per year, and the rest of the basin, which receives about 500 mm per year. Currently the Pangani River provides 17% of the hydroelectric power for Tanzania requiring significant stream flow. It is predicted that the demand for water by urban users in the basin will double by 2015, further stressing the water supply (*3*). As a result of spatial rainfall variability, projected increase in population, growth in agriculture, the recognized need for environmental flows, and increased demand by current and future users, allocation of water within the basin is a contentious issue.

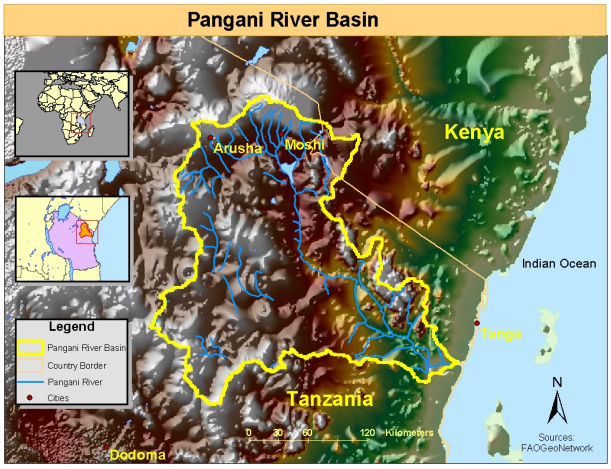

Figure 2. Map of the Pangani Basin

The Current Water Regime

The current water management regime in Tanzania is rooted in colonial law, specifically the Water Ordinance of 1923. The ordinance introduced a water rights system that facilitated colonial settlers' access to water resources. It also established that all rights to surface water, groundwater, and land in Tanzania were vested in the state. Current laws maintain these principles. Tanzania's water supply is legally governed by an administrative allocation system. Any abstraction from surface waters, except for minor water collection using buckets, or groundwater extraction of more than 22,700 L per day requires a permit. The cost of a permit ranges from $35 to $40 USD and must be renewed annually (*4*). This is a significant cost for most users considering the per capita gross national income of $280 USD (*5*). Water rights currently do not expire and many were issued decades ago. The only way to transfer rights between users is through the sale of land. However, much of the water extracted for irrigation is taken by individuals or groups without water rights (*6*) The former water allocation system was an informal, user-based riparian system, and remnants of this system still exist today.

Measuring the Impact

The impacts of an increase in rice prices on water demand need to be measured in order to see whether the current water allocation system would be able to handle the additional stress. A model is developed for the Pangani Basin that takes the price pass-through (0.38) for rice to determine the impact a change in world price will have on local prices in Tanzania. Three supply response values (0.37, 0.92, 1.33) are used to determine the response of farmers rice production to the change in local prices. Rice yield, estimated for the basin, is used to convert projected production to projected area of cultivation. The area of cultivation and average water requirement—156 mm for an acre of rice within the Pangani Basin—are used to estimate the increase in water demand as world prices double, as projected by the World Bank.

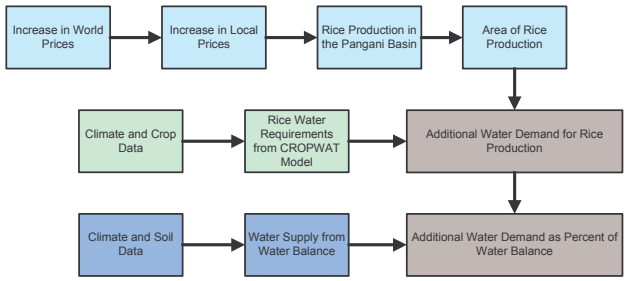

Figure 3. Flow chart of the how the impacts of world price can have on water demand

The water requirements for the production of rice in the basin are calculated using CROPWAT, a model developed by FAO. CROPWAT accounts for local precipitation, potential evapotranspiration, crop growth coefficients, and the growing period of the crop to determine crop water requirements. The crop water requirements are calculated using a grid, which divided the basin into 144 squares each of which are 256 km^2. A sensitivity analysis is conducted on the results by varying crop yield, supply response, and average irrigation requirements.

A water balance for the Pangani Basin allows us to quantify the water demand for rice production relative to the available supply of water in the basin. A vertical water balance is applied to the same grid as used by CROPWAT and calculates the water supply for smaller sub-catchments. The water balance indicates that the Pangani Basin has an available water supply of approximately 315 million m^3 within the streams during the growing season of rice.

The results indicate that a doubling of the world price of rice would lead to an increase in rice production and an additional 0.1-8% percent increase in the demand for water from the available supply. While the values alone may not seem significant, when put into context with the current situation, this increased demand may contribute to the larger problem of water allocation in the Pangani Basin.

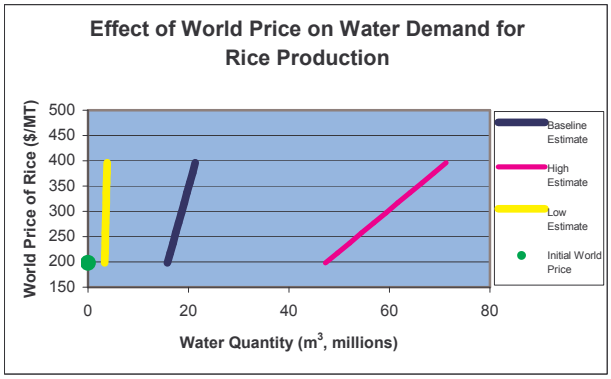

Figure 4. Estimates of water increase due to price

	Baseline Estimate	High Estimate	Low Estimate
Additional Rice Water Demand (m^3)	5,554,452	24,011,046	470,474
Water Supply for Basin, Based on Water Balance (m^3)	315,521,354	315,521,354	315,521,354
Additional Demand as Percent of Water Balance	2%	8%	0.1%

Figure 5. Estimates of water increase in percent

Managing the Impact

The current water allocation regime in the basin is evaluated to determine if it can adjust to future shifts in demand. The current regime suffers from problems due to a lack of enforcement of water rights. In addition, the regime may not have the flexibility to handle sudden shifts in demand since the water allocation permits are often provided for many years. As water demand increases, mechanisms that manage the resource are often challenged to cope with emerging allocation issues. To identify strengths, weaknesses, opportunities, and threats of the current system, an evaluation using a set of criteria is necessary.

Many different criteria can be used to evaluate water allocation mechanisms. While many criteria have been suggested in the literature, other options may be applicable. Munger (2000) points to a set of five meta-criteria to which all criteria in an analysis should satisfy:

- Criteria should focus on ends, not means
- Each criterion should be stated clearly and precisely enough to imply a measure for how well it is satisfied by an alternative
- All else being equal, a set of criteria is better if trade-offs can be quantified
- The set of criteria should be complete accounting for all the concerns of all citizens
- Criteria should address separate aspects of the policy problem, so that satisfaction of each criterion is mutually exclusive.

Using the set of meta-criteria one can develop criteria that are appropriate for the analysis of the situation or problem at hand. Additionally, it may be beneficial to revise criteria that have already been used by others and suggested.

Therefore, 13 criteria were developed to provide the basis for evaluation of the current Tanzanian allocation system, which is a mix between public administrative water allocation and user-based allocation. Some of the applied evaluation criteria and rationale for scores are listed in the table below with a score of low being undesirable. The justifications for the ranking were given; if the criteria were left blank the information needed to formulate a ranking was given in the rationale. The scores represent estimates and are useful as guides but should be interpreted as a best judgment. Note that some evaluation criteria could not be scored because of inadequate information.

Following is an example of three of the criteria, including the ranking and rationale as applied to the current Tanzanian system.

Criteria	Tanzania	Rationale
Equity	Low	1. High permit costs favor the rich 2. Illegal abstractions 3. Upstream users
Environmental Impact	Medium	1. No provision for environmental flows
Economic Efficiency	?	1. Information is needed on how much money it costs to run the system and how money is generated 2. Need clearly defined goals

Figure 6. Criteria and ranking table

Based on all the criteria used to evaluate the Tanzanian system, we have generated suggestions that may improve the current system. Suggestions include: establishing clearly defined goals of the system, monitoring water availability, conducting studies to determine essential stream flows, creating incentives to purchase permits and or penalties for free-riders of the system, establishing permits that adjust in proportion to supply and that expire, allowing permits to be traded and retracted, and encouraging public participation by incorporating stakeholder involvement.

Conclusions from Case Study

The Pangani Basin will face an increase in the water demand for agriculture if world rice prices continue to rise. While the level of increase in demand may vary, changes in demand will impact a large portion of the population. With additional stress on the Basin's current water allocation system it may be beneficial to adjust the system based on the criteria formulated in this case study.

Lessons Learned

The project concludes with several insights into measuring and managing water demand at a basin level and some broader lessons on institutional behavior.

1. Data collection and monitoring relevant to demand evaluation and policy planning are often not available on a basin level, making it difficult to identify demands and prescribe good policy. For future basin level planning, it would be beneficial to have social, economic, and biophysical data on compatible spatial and temporal scales.

2. The causal chain between world prices and local production contains complex variables, which should be understood with reasonable confidence in order to accurately predict the outcomes of a price change.

3. To understand the full effects of policies, the sector examined should be viewed in context of other affected institutions, ecological and economic entities.

4. To evaluate how well the management system can adjust in practice to increasing demands, roles of both formal and informal institutions governing the resource should be considered as well as the dynamics between other relevant institutions.

5. Institutions governing water resources should be flexible and able to change with the shifting demands and developments of the basin in order to persist.

6. For resource reallocation to be feasible, it must be compatible with property and use rights.

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Acknowledgments

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