Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 18 Article 6

2017

Risk Mitigation through Diversified Farm Production Strategies: The Case in Northern Mozambique

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Risk mitigation through diversified farm production strategies: the case in Northern Mozambique

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Abstract

Mozambique, like many other parts of the low-income world, faces perennial challenges with food security. With a rapidly growing population and arable land on the decline, sustainable agriculture is vital to managing the already depleted natural resources of Sub-Saharan Africa more effectively while increasing food security. Food security issues for subsistence farmers in most low-income countries are a product of endogenous (crop yields) and exogenous (currency fluctuations as many agricultural inputs are imported) factors. In Mozambique the value of the local currency, meticals, has decreased by approximately 50% since January 2015 compared to the U.S. dollar. While this makes exporting products out of Mozambique more attractive in a relative sense, it negatively effects those industries which rely on imported inputs such as animal feed and inorganic fertilizer. In response to this exogenous currency crisis, research was conducted in Nampula, Mozambique during the summer of 2016 on a method for implementing crop diversification to reduce the risk that accompanies the devaluation of the metical. This research was undertaken on a poultry operation which is heavily dependent on imported maize and soya. Similar to the market structure of the poultry industry in the United States, all birds are grown by individual out growers who typically also have small plots of land to farm. Objectives for the project included 1) perform on-site crop production evaluations, 2) determine profitability for various row crops, and 3) simulate alternative production practices to increase crop profitability. Of the crops grown (tomatoes, maize, and cabbage), maize required the least labor, lowest initial investment, and the highest probability of breaking even. This research concluded that if poultry producers in Mozambique who rely on imported feed grew maize simultaneously it would reduce the dependency on imported maize and reduce income variability associated with exogenous currency fluctuations. Implementing a program such as this could increase revenue streams as well as reduce variability, thereby enhancing regional food security.

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Meet the Student-Author

Olivia Caillouet

I am from Little Rock, Arkansas, and graduated with honors from Little Rock Central High in 2012. I graduated in December 2016 from the Dale Bumpers College of Agricultural, Food and Life Sciences with a degree in Horticulture and minor in Sustainability. This research was presented at the National American Society for Horticultural Science (ASHS) undergraduate oral paper competition in Atlanta, Georgia, August 2016 and at the International Society for Horticultural Science (ISHS) Conference in Montevideo, Uruguay November 2016.

During my time at the University of Arkansas, I have served as the Horticulture Club treasurer and vice president; worked as the Bentonville Farmer's Market Assistant Manager; completed an internship on a certified organic citrus farm in Big Sur, California; and was a summer intern at a farm in Adjuntas, Puerto Rico. I have also completed research at farms in Arkansas and Mozambique. I plan to pursue a Master's Degree in Agricultural and Extension Education, then embark upon my career focused on education outreach.

I would like to thank Dr. Lanier Nalley for his help and support throughout this research process. Dr. Amy Farmer was a crucial component to the success of this project, and without her it would not have been possible. I would also like to thank Dr. Dustan Clark for his insight while in Mozambique. Last, I would like to thank Dr. Wayne Mackay and the Department of Sustainability for allowing this project to serve as an interdisciplinary learning experience.

Introduction

Challenges for Mozambique

The Food and Agriculture Organization of the United Nations (FAO, 2007) described Mozambique's agriculture as strongly bipolar, split between 3.2 million small-scale farmers, producing 95% of agricultural gross domestic product (GDP), and about 400 commercial farmers producing the remaining 5%. The population of Mozambique is approximately 28 million (World Bank, 2016) with a reported poverty rate in the northern state of Nampula, where this study took place, between 50% and 70% (JICA, 2010). The National Profile of Working Conditions in Mozambique (ILO, 2009) reported that 40% of the employed population was involved in some part of the agriculture industry. Furthermore, employment in the agriculture sector was found to offer the lowest wages of all jobs accessed.

Poverty in Mozambique is also influenced by evolving climatic events. The 2015 and 2016 cropping seasons were some of the most drastic drought years recorded in sub-Saharan Africa. The Famine Early Warning Systems Network (FEWSN, 2016) reported that southern Africa was in the second year of drought related to the El Niño years of 2015 and 2016 and the drought was expected to increase as the 2016 year continued. Drought impacts coupled with the devaluation of the local currency, meticals (mets), has increased the risk for farmers in Northern Mozambique who produce goods that rely on rain and imported inputs, such as maize, soya, and poultry. According to CoinMill (2016), as of August 2016 the metical was at an exchange rate of 67 mets to $1, and the metical was predicted to continue to lose value.

With almost half of the working population in the agriculture sector, there is a need to increase production efficiency and profitability of crops to increase farm revenue and decrease farm revenue variance. Reducing yield variance can help both producers and consumers as consistent yields also provide consistent consumer prices. The Poverty Reduction Action Plan (PRAP, 2011) stated the solution to addressing poverty in Mozambique included:

1. increasing economic productivity through family farming,
2. promoting general employment, and
3. increasing human and social development.

There is a need for sustainable practices for feeding and employing the people of Northern Mozambique to promote economic growth and development. Sustainability is essential in this part of Mozambique; with the discovery of natural resources such as coal and natural gas, there has been a recent influx of foreign direct investment (FDI) to extract said resources. On the surface, this FDI looks attractive as regional GDP increases but looking closer one finds signs of Dutch Disease where local economies are focusing only on extraction of resources and abandoning investment in traditional sectors of the economy (Corden, 1984). Moreover, while coal and natural gas can boost GDP, there is little taxation on these foreign firms and even less reinvestment (schooling, hospitals, etc.) into the local Mozambican communities. Problems such as this plague Sub-Saharan Africa. Thus, sustainable agricultural practices that do not rely on foreign investment and in fact protect against fluctuation (in the form of local currency fluctuations) were investigated.

Sustainability in Farming Production Practices

Mozambique has consistently struggled with macro-economic issues such as currency devaluation and continues to struggle with poor soils (due to lack of fertilizer), lack of rainfall (due to frequent droughts), and lack of agricultural inputs (due to currency devaluations). As such, sustainable agricultural programs are of utmost importance to combat the growing food insecurity issues in the face of climate change. Sustainability in agricultural systems incorporates concepts of resilience (capacity for systems to buffer shocks and stresses) and persistence (a system's ability to continue for extended periods of time) while taking into consideration social, economic, and environmental outcomes (Pretty, 2007). Furthermore, Smith (2013) explained that reduced income variability can be achieved by growing multiple crops which includes, but is not limited to, choosing crops with different growing seasons or maturity dates, mixing livestock and plant crops, and raising different types of livestock.

This research was conducted at New Horizons poultry farm where employees help diversify their risk by growing other crops, as poultry is inherently risky. That is, if a disease is to infect one bird there is a high likelihood that it infects all birds. These employees are termed "out growers" which are family operations that grow poultry to maturity then sell the birds to New Horizons in exchange for chick supply, poultry feed and support building grow houses. These poultry out growers also raise crops on the side to ensure their food security even if their poultry profits are marginalized by disease. Furthermore, New Horizons is pursuing contracts with out growers to produce maize on their farms instead of traditional crops such as cassava, beans, and sorghum because poultry feed mainly consists of maize and soya. The idea with out growers producing maize is that they would have a guaranteed market (New Horizons) and a guaranteed price to lock into, if they so choose. This would decrease revenue volatility as producers would not be subject to a fluctuating domestic market price, New Horizons would have a guaranteed supply of maize at a locked-in price that would not be subject to foreign exchange rates. This would appear to be mutually beneficial, but only under the context that out growers could produce enough maize to cover their input costs. Also, yield variability may pose profitability issues given the current drought in Sub-Saharan Africa and the fact that maize requires a relatively large amount of water.

Many low-income producers often prefer income stability over income maximization (Nalley and Barkley, 2010) and, as such, this study provides poultry producers in Mozambique an insurance tool through crop diversification that can smooth revenue from destabilizing exogenous factors such as currency devaluation. Implementing a program such as this aims to both increase total income as well as reduce income variability. Our results indicated that if small-scale poultry producers could simultaneously raise maize on small plots they could earn additional income and stabilize domestic prices of maize, which could increase food security as well as producer livelihoods.

The idea of vertical integration, poultry out growers selling maize to poultry feed mills in Mozambique, has the opportunity for a mutually beneficial realtionship. Poultry feed mills could reduce risk from volatile currency fluctuations which can drastically effect the price of imported maize. Poultry out growers could increase their revenue stream and simultaneously reduce variance by diversifying their income and locking in a price for maize before the growing season with a local feed mill. This research has provided a foundation for further study on the relationship between row crops (horticulture and agricultural row crops) and poultry production practices that take place in Northern Mozambique. The ability to research other row crops beyond maize could further diversify poultry producers cropping systems and could open up the ability to improve soil fertility through strategic crop rotations. Conservation crop rotation is a systematic sequence of crops grown in combination with grasses and legumes, which has been found to help maintain cropland sustainability (USDA, 1996). Nampula experiences high pest pressures in combination with poor, sandy soils that highlighted the need to incorporate crop rotations. Fewer problems with weeds, insects, and fungi have been linked to crop rotations, thus the need for fungicides, pesticides, or insecticides that are expensive and difficult to obtain could be reduced (USDA, 1996).

The research seeks to improve the economic sustainability of small-scale farm systems through reduced income variability and increased yields. Furthermore, this research aims to determine profitability of various row crops (tomatoes, maize, and cabbage) and to inform Mozambicans on practices to increase economic returns and reduce volatility.

Materials and Methods

This study was conducted in collaboration with New Horizons poultry farm in Nampula, Mozambique (15°04' 23.1"S 39°11'40.0"E) (Google, 2016). While New Horizons focuses on poultry production, its goal is to ensure a consistent supply of poultry. As such, New Horizons encourages out growers to have a crop farm as well as raise poultry.

To stabilize income for out growers and market prices for New Horizons, New Horizon out growers producing alternative crops were evaluated at Ebenezer Agriculture Apprentice Program (EAAP), an organization under the management of New Horizons Farm, aimed at teaching youth in the community practical farming techniques. Crops were evaluated by analyzing past data sets for:

1. yearly cost of crop production,
2. yearly crop yields, and
3. yearly market price of crops.

When data were not available, the estimated ranges were obtained for the three variables listed above through discussion with the farm manager as well as locals. The data were then entered into the structural framework for profitability to determine profitability of crops for producers (Fig. 1). This information was entered into a statistical program @Risk® (Palisade Corp., Ithaca, N.Y.), via a Monte Carlo simulation, where each crop was simulated 10,000 times to determine the outcome for profitability. For this study, risk is not solely defined as the probability of breaking even, but rather profit smoothing through diversification of agricultural production.

Tomatoes

Tomatoes have the potential to be profitable, but also pose several marketing and production problems. First, tomatoes require daily watering which has to be done by hand in Northern Mozambique as irrigation equipment is expensive. Second, given that tomatoes are a fresh product with no preservation methods (canning is not practiced in Northern Mozambique), price can be high one day (if you are the first to market) and low (almost free) the next as everyone in a community harvests and sells simultaneously. Our tomato data collection began with past yields from the 2015 season. There were 16 apprentices that worked field plots in 2015 and 2016 which provided spatial and temporal variation.

Tomato plots are typically watered by hand so drought conditions can be mitigated through hand irrigation. Plot sizes varied and were calculated in meters (m). Five apprentices managed (30 m × 15 m) plots and 11 apprentices managed (15 m × 15 m) plots in 2015. The yields from each plot in 2015 were gathered by weight, kilograms (kg). The 2016 growing season had the same production inputs as 2015, which included labor, seeds, fertilizer, fungicide, and insecticide (Table 1). The 2016 field plots were all (10 m × 10 m). The yields and production costs from 2015 were calibrated in @Risk® to equal that of a 10 m × 10 m plot. This kept uniformity in data sets and allowed for comparisons between years for grower percent profitability. The last step for tomato data collection was to determine the range for 2016 market price of tomatoes (Table 1). This was done by verbal communication with the farm manager. The 2015 yield data are represented by "A", on Fig. 2, while 2016 yields with a 50% increase in yields compared

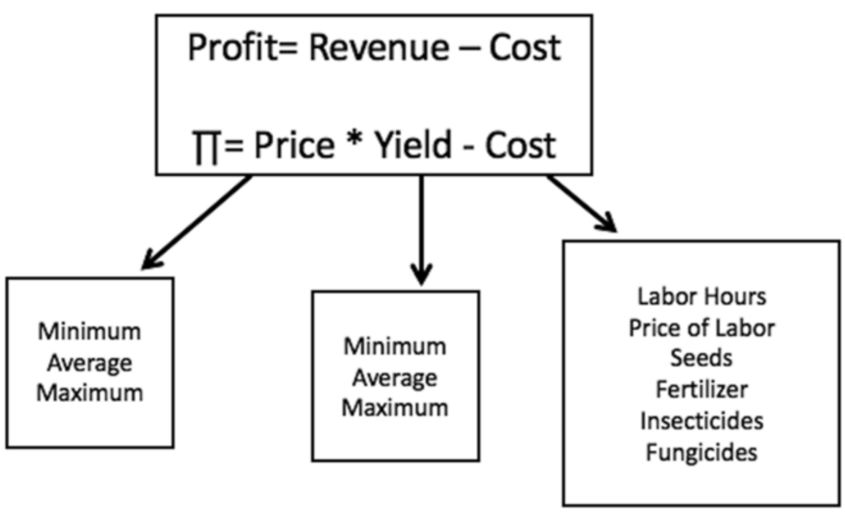

Fig. 1. Structural framework for profitability (Lawton Nalley, pers. comm. 2016). ∏= Profit.

to 2015 are “B”. A 50% yield increase was determined for 2016 based on communication with the EAAP Farm Manager and the expectation of how increased apprentice education would also increase fruit production.

Maize

The cost of maize production included labor, seed, and urea fertilizer (Table 2). Maize production differed from other crops evaluated because yields and price of crops were based on number of cobs per plot during the first harvest (harvest 1) as well as dry maize sales collected in the second harvest (harvest 2) (Table 3). The range of cobs per plot was determined by the number of stalks per plot multiplied by either 1 cob per stalk (minimum) or 2 cobs per stalk (maximum) and then those values were used for the average. The yields were collected from 13 field plots (50 m × 50 m), which were all grown with the same production practices. The 2016 yield data are “A” on Fig. 3, while the future 2017 yields with a 30% decrease in market price are “B”. All other factors remained the same for maize production in the structural framework equation (Fig. 1). Furthermore, the market price was reduced for the future

Table 1. Total cost range for all inputs for 17-week tomato production cycle of 10 m × 10 m plot and market prices, Nampula, Mozambique, 2016.

Range	Labor (mets[a])	Seeds (mets)	AN[b] fertilizer (mets)	N-P-K[c] fertilizer (mets)	Spray fertilizer (mets)	Fungicide (mets)	Insecticide (mets)	Total cost (mets)	Market price (mets/ kg)
Minimum	7650	900	278	325	452	105	144	9854	25
Average	9563	1125	464	541	452	105	144	12,394	40–60
Maximum	11,475	1350	928	1083	452	105	144	15,537	90–100

[a] Metical currency.
[b] Ammonium nitrate fertilizer.
[c] Nitrogen-Phosphorus-Potassium fertilizer.

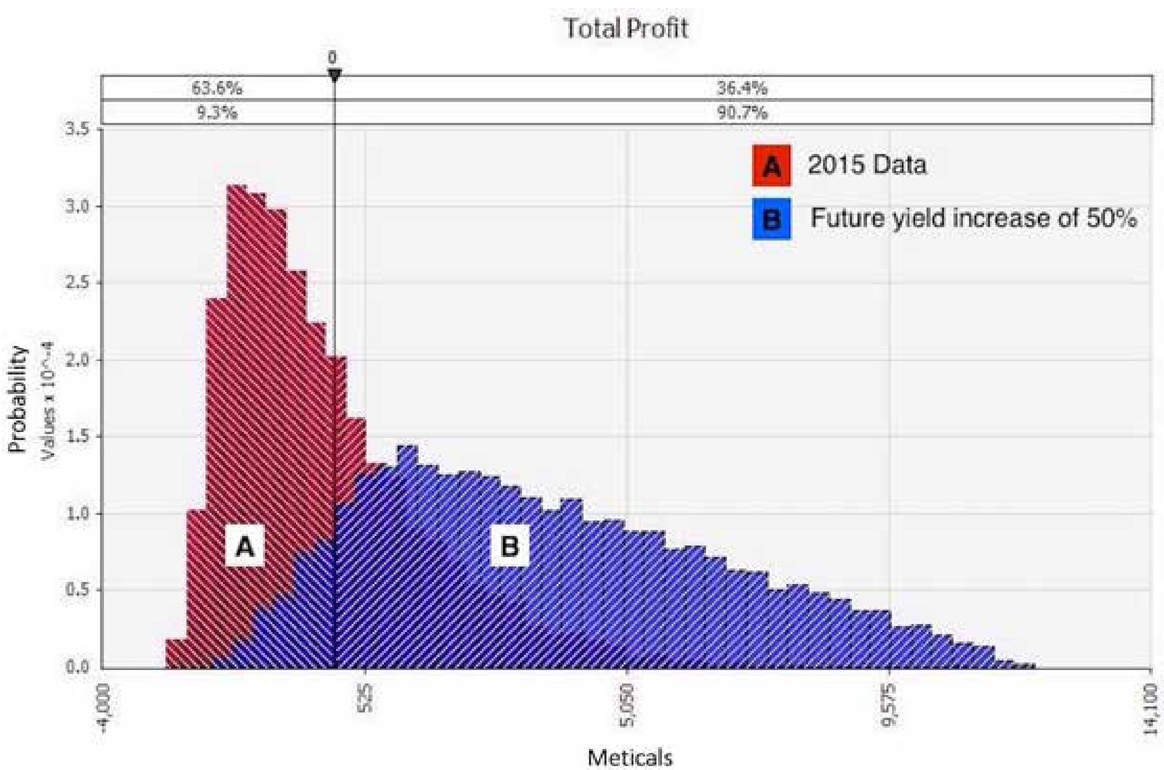

Fig. 2. Past and future profitability for tomatoes, Nampula, Mozambique, 2016. The percentages at the top of the figure represent the “A” data as having a 63.6% profit loss probability and 36.4% profit probability. The “B” data has a 9.3% profit loss probability and 90.7% profit probability. The vertical bar represents the point at or below where growers do not make a profit.

Table 2. Total cost range of maize production for 20-week maize production cycle of 50 m × 50 m plot, Nampula, Mozambique, 2016.

Range	Labor cost (mets[a])	Seed cost (mets)	Urea cost (mets)	Total cost (mets)
Minimum	4050	1080	7000	12,130
Average	6750	1080	7000	14,830
Maximum	9450	1080	7000	17,530

[a] Metical currency.

Table 3. Maize yields per 50-m × 50-m plot and total market price for yield, Nampula, Mozambique, 2016.

Range	Harvest 1 (Cobs[a])	Harvest 2 (kg[b])	Corn on the cob (mets[c]/ cob[d])	Dry maize (mets/ kg)	Total market price (mets)
Minimum	5346	98.5	3	5	16,530.5
Average	8019	450.5	3	15	38,833.5
Maximum	10,692	883	3	30	58,566

[a] Corn on the cob yields that were harvested March 2016.
[b] Kilograms of harvest 20 May 2016.
[c] Metical currency.
[d] Corn on the cob was sold in bags (100 cobs per 300 meticals).

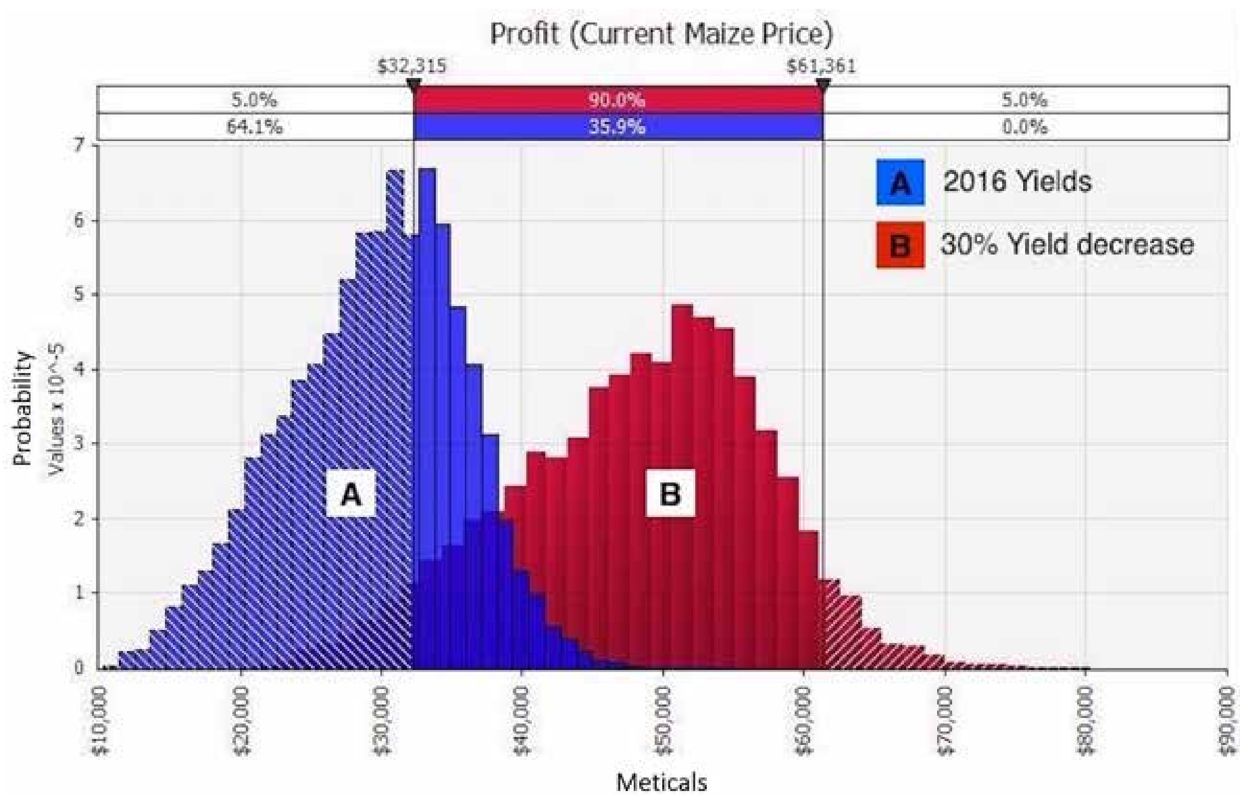

Fig. 3. Current maize yields and maize with 30% price decrease, Nampula, Mozambique, 2016. The percentages at the top of the figure represent "A" data as having a 64.1% probability of making 10,000-32,315 meticals (mets) and 0% probability of making 61,361-80,000 mets. The "B" data has a 5% probability of making 10,000-32,315 mets and 5% probability of making 61,361-80,000 mets. There is 35.9% probability that "A" will return between 32,315-61,361 mets, while "B" has 90% probability between 32,315-61,361 mets.

because it was not expected that the current maize price impacted by drought and limited supply would remain the same.

Cabbage

Cabbage plots were planted around the middle of March 2016 and were estimated to be harvested 13 June 2016, which totaled 13 weeks of production. Total cost of production included labor, seeds, fertilizer, and insecticide (Table 4). This was the first year for cabbage to be grown at EAAP and, as such no past data were available. However, estimated price ranges for cabbage at Nampula markets was verbally collected from locals. In addition, based on observations in the field, the range for crop yields was determined. Costs were determined for hand watering practices versus the use of drip irrigation, which reduced the cost of labor, to determine if investing in irrigation supplies had minimal risk.

Results and Discussion

Tomatoes

The results for tomatoes used the data collected during the statistical analysis through @Risk®. The 2015 data are represented by the letter "A" and the estimated 2016 yields are shown by "B" (Fig. 2). The black vertical line on Figs. 3 and 5 represents the breakeven point where below (to the left of) producers lose money. The 2015 data set on Fig. 2 are high in probability (*y* axis) which represents that growers were more likely not to make a profit than 2016 yields. We estimated that in 2015, growers lost money 64% of the time and lost an average of -182 mets per 10 m × 10 m plot (Fig. 2). It is worth noting that 2015 yields were said to have been low. In addition, the local market was flooded by another tomato producer. The term "flooded" refers to oversupply, which can decrease demand and the market price of crops.

The 2016 yields are a simulation that predicts what profitability could look like for growers if 1) the market were not flooded, and 2) yields per plot were increased by 50% (min., avg., and max.). Agricultural teachers at the EAAP indicated they thought their students were capable of increasing their tomato yields by 50% with more training. Although Fig. 2 shows a larger variance in profitability, the risk is upside not downside risk. That is, with the chance of yielding more (but keeping the floor constant) the overall risk variance increases but only positive risk (to the right on the figure) which indicates making more money. If tomato yields could be increased by 50% moving into the future and the market were to not be flooded, growers could go from making a profit 36% of the time to 91% of the time. Furthermore, average profits would increase from -182 mets to 3696 mets per plot. These results inform growers that in the past tomatoes have not been a crop with high profitability, but if several changes were made to the production cycle, tomatoes could be a viable crop to grow in the future (Fig. 2).

Maize

Maize production was found to require the least inputs as well as the lowest up-front investment for the cropping cycle, both attributes that are attractive to low-income farmers. However, Bundy (1998) states that maize uses substantial amounts of nitrogen (N), phosphate (P_2O_5), and potash (K_2O). Furthermore, the nutrients taken up by the plant must be supplied by the soil reserves or by adding nutrients and a deficiency of any nutrients may reduce yields (Bundy, 1998).

Using the information that was collected as described in the materials and methods section, the results for 2016 yields and future crop profitability, with 30% market price decrease, were determined in @Risk®. Due to the ability to rely on rain-fed irrigation, the cost of production is lessened because of the reduction in labor needed for hand watering. While maize has profitability benefits when compared to tomato and cabbage, it is not expected that these benefits will sustain if maize is grown continuously. Roth (1996) states that crop rotations contribute enhancements in yields, soil physical properties related to plant growth and is essential to the control of crop-disease problems.

Table 4. Total cost for all inputs for 13-week cabbage production cycle of 10 m × 10 m plot and market prices, Nampula, Mozambique, 2016.

Range	Labor (mets[a])	Seeds (mets)	N-P-K[b] fertilizer (mets)	Spray fertilizer (mets)	Insecticide (mets)	Total cost (mets)	Market price (mets/ 1 cabbage)
Minimum	4388	900	302	452	144	6186	20
Average	6581	1125	806	452	144	9108	40
Maximum	8775	1350	1915	452	144	12,636	60

[a] Metical currency.
[b] Nitrogen-Phosphorus-Potassium fertilizer.

The letter "A" represents 2016 yields where growers were found to make a profit 100% of the time (Fig. 3). Profits for 2016 came with an average of approximately 48,190 mets per plot. These results may be misleading as in 2015 and into 2016 there was a drought across the entire continent of Africa which increased the demand for maize as well as the market price. It is not anticipated that the 2016 price for maize will remain at this level as the drought subsides and producers react to market prices. So, a simulation was conducted in @Risk® where the price for maize was decreased by 30%, to mimic a larger regional maize supply, while all other factors of production remained the same.

The data set with the letter "B" on Fig. 3 represents the future profitability of growers with the price of maize decreased by 30%. It was estimated that growers still made a profit 100% of the time. However, growers would go from making an estimated 48,190 mets per plot to 29,460 mets per plot. These results ensured that given past data yields and future anticipations for 30% price decrease, maize is a crop that is in high demand with limited risk for growers (Fig. 3). Again, it should be noted that being profitable 100% of the time is not feasible, these data suggest this under two important assumptions. First, all maize farmers have gone to a technical school to learn how to grow maize. This includes access to fertilizer, disease diagnosis, etc. Second, there is ample rainfall/water supply to make a crop. When working with New Horizons the first assumption (schooling) will be provided, but the second assumption is not dependable and our results would most likely change if we had a more robust dataset.

Cabbage

During 2016 was the first year that EAAP grew cabbage. Therefore, the profitability analysis was completed without past yield data sets. Using @Risk®, the percentage of time growers would make a profit was determined with and without the use of drip irrigation. It is important to determine if cabbage could be more profitable with drip irrigation prior to making the financial investment to obtain the necessary equipment. This analysis took into consideration the ranges for cost of production, estimated yields as well as market price per head of cabbage. The "A" data set on Fig. 4 represents the outcome if growers were to continue hand watering without the use of an irrigation system. With the practice of hand watering growers lost money 37% of the time and had an average income of 724 mets

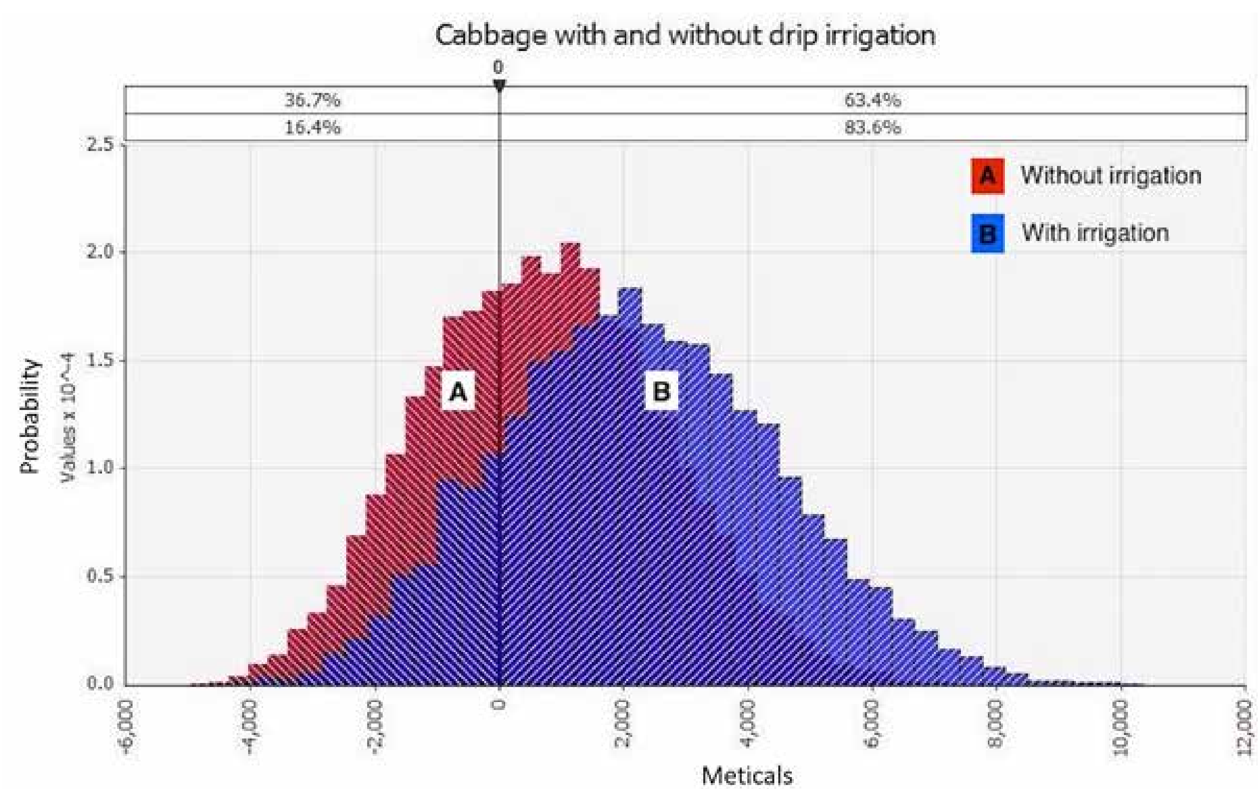

Fig. 4. Predicted cabbage yields with and without drip irrigation, Nampula, Mozambique, 2016. The percentages at the top of the figure represent the "A" data as having a 36.7% profit loss probability and 63.4% profit probability. The "B" data has a 16.4% profit loss probability and 83.6% profit probability. The vertical bar represents the point at or below where growers do not make a profit.

per plot. While the average profit of 724 mets is greater than zero, it is misleading because without irrigation, over one-third of the growers were losing money.

The "B" data set on Fig. 4 represents the outcome if growers were to implement a form of drip irrigation. Drip irrigation is a specific type of irrigation system that is either above or below ground and is a more resource-conservative form of applying water to the base of plants. The use of this technique would avail the opportunity to grow crops during the dry season when hand watering is not an option. The demand for the crop would be greater in the dry season, while the market price of the crop would have also increased. Growers could go from making a profit 63% of the time without irrigation, to 84% with irrigation. This increase in the percentage of crops making a profit is related to shifting the timing of production which increased demand, market price, and reduced cost of labor. Drip irrigation decreased the amount of time spent by workers to water plants by hand and thus reduced the total cost of inputs.

For this analysis the cost of the drip irrigation was not taken into consideration, because it was seen as a "sunk cost". The term "sunk cost" refers to the concept that over time the cost of the irrigation would be negligible. This simulation represented that if growers were to implement the horticultural technique of irrigation, it would increase the percentage that growers would make a profit. These results confirmed that risk could be reduced with a shift in production practices (Fig. 4).

Conclusions

These areas for future research would further enable poultry growers in Mozambique to increase farm productivity through row crop diversification, provide jobs, and address human and social development issues outlined by PRAP. The results of this study are important on several levels. First, it appears that maize can be the most profitable to small-scale producers out of the three crops evaluated in Northern Mozambique. Second, via the @Risk® simulation, it also appears that maize production provided a stable source of income (high percentage of breaking even) which is important for food security, stable food prices, and producer livelihoods. Last, maize production by small-scale producers can benefit the up-and-coming poultry industry in Mozambique which has provided much needed inexpensive protein, in the form of eggs and meat, via reduced maize price through a mechanism not subject to foreign currency fluctuations.

Acknowledgments

This research was made possible by a State Undergraduate Research Fellowship (SURF), an Honors College Study Abroad Grant, and Dale Bumpers Creative Research Grant. Funding to present at the National American Society for Horticultural Science conference was supported by an Honors College Travel Research Grant. Furthermore, funding to present research at the International Society for Horticultural Science Conference in Uruguay was made possible by the University of Arkansas Dale Bumpers College of Agriculture, Food and Life Sciences-Undergraduate Research and Conference Travel Award. This research was supported by New Horizons Farm and Ebenezer Agriculture Apprentice Program in Nampula, Mozambique. Support also provided by the University of Arkansas System Division of Agriculture.

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