



Evaluating Economic Viability of Large Fish Solar Tent Dryers

Levison S. Chiwaula¹ · Collen Kawiya¹ · Patrick S. Kambewa¹

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Abstract Effectiveness of solar tent dryers in agricultural products has been well documented, but this information may not be generalised for use of solar dryers in all agricultural commodities and for all sizes of solar dryers. As such, we evaluated the economic viability of large capital intensive solar dryer that has been designed to dry small fish species on commercial basis on Lake Malawi. A probabilistic net present value (NPV) analysis was applied to a 15-m-long by 8-m-wide solar tent dryer which costs MK1,513,850 (US\$2100) to construct and has a maximum carrying capacity 850 kg of fresh fish. The results show that the base NPV of this solar tent dryer is MWK5, 838,482.11 (US\$11,762). When risk and uncertainty are considered, the probabilistic NPV becomes MWK12, 268,503 (US\$24,716). The probability of obtaining a positive NPV was 58%, and we found that NPV is highly sensitive to total revenue and total cost but not to their components. We conclude that investments in large solar tent dryers are economically viable and that viability would be enhanced through access to formal fish markets where prices are stable and high.

Keywords Solar tent dryer · Economic viability · Risk analysis · Net present value

Introduction

The increase in demand for food due to population and income growth has raised the need to increase food supply. Until recently, efforts to increase food supply have mainly been through increase in agricultural productivity and increase in cultivated area. It is, however, noted that one of the cost-effective means of increasing food supply is through reduction in postharvest losses [17]. The fisheries sector is one such sub-sector of the agricultural sector where postharvest losses are very high because of the perishability of the commodity as well as poor postharvest handling methods and techniques. For example, the Food and Agriculture Organisation (FAO) estimates the fish postharvest losses in Africa at 40% [11], while a recent

meta-analysis estimated the fish postharvest losses in Africa at 27.3% [1]. This means that efforts to increase fish supply to meet the increasing demand for fish would be met by reducing these postharvest losses. The World Bank reckons that investment required to reduce postharvest losses is relatively modest and the return on that investment rises rapidly as the price of the commodity increases [17]. Particularly for fisheries, increasing fish supply would mean increasing fishing effort in capture fisheries or increasing aquaculture production. Increasing fishing effort in capture fisheries would threaten sustainable use of the fishery resources that have common property characteristics.

To reduce fish postharvest losses, a fish solar tent dryer has been adapted to small fish species of Lake Malawi [4]. Drying is a water removal process from foodstuffs commonly used for preservation and storage purposes. Fruits and vegetables are the most important products in agriculture sector [11]. Fish solar tent drying is an old technology which was first used in Bangladesh [1]. The technology has also been used in other agricultural

✉ Levison S. Chiwaula
lschiwaula@cc.ac.mw

¹ Department of Economics, University of Malawi,
P.O. Box 280, Zomba, Malawi

products such as fruits and vegetables. For example, in Egypt the technology was developed to preserve fruits and vegetables [4]. Using locally available materials, small-scale farmers could construct driers which were able to produce high quality and with cost–benefit analysis of 1 to 2 year payback period. This contrasts with gas- or oil-heated driers common in developed economies.

The technology is introduced because it is argued that most of the fish postharvest losses are due to poor processing methods [11]. Presently, about 90% of fish captured in Malawi are consumed after being processed using traditional processing methods which include fish smoking, sun drying and para-boiling [10]. The solar dryer that is being assessed is 15 m long and 8 m wide and has the maximum carrying capacity 850 kg of fresh fish, and this enables commercialisation of fish processing (Fig. 1).

A fish solar tent dryer enables fish to dry in all weather conditions and in a clean environment, and this ensures reduced quantitative and qualitative postharvest losses. Solar tent drying is a technology that has been proven as efficient and effective in drying agricultural products [7, 16]. Solar tent drying in fish has fast drying rates and good nutrient retentions and improves quality of dried products [4, 16]. Solar tent drying also saves energy and time, thereby making them environmentally friendly [7].

The benefits of a solar tent dryer can be realised only when the technology is adopted by the fish processors. However, for fish processors or entrepreneurs to construct and use solar tent driers, there should be adequate economic incentives. Adequate economic incentives exist

when the present value of net benefits of fish solar tent driers is expected to be greater than the present value of net benefit of open sun drying. This information is hardly available. The information that is available is about investment decision behaviour on other agricultural technologies [3, 12, 13]. In this paper, we assess whether investments in solar tent driers are economically viable by using investment appraisal techniques as well as the effect of risk on the economic viability of the investments. This information has potential to interest policy makers and potential entrepreneurs.

Materials and Methods

Analytical Approach

Assuming that the fish processor's objective is to maximise profit, the net present value (NPV) analysis becomes the appropriate tool to appraise fish processor's decisions to invest in a new technology such as the fish solar tent dryer because its life span is more than one. NPV analysis is a standard methodology in agricultural economics for assessing capital investments such as farm tractors [9] which is theoretically sound [15]. The NPV is also the most popular and sophisticated economic valuation technique [8]. It is defined as the sum of the investment projects' cash inflow and cash out flows, discounted at a rate which is consistent with the investment projects' risk [5, 9, 10, 16]. The NPV is thus the difference between the sum of the



Fig. 1 Diagram of the fish solar tent dryer on Lake Malawi

present values of the future cash flows, and the present value of the cash outflows [6]. Under the NPV approach, a fish processor would compare the net present value (NPV) of the expected benefits with the net present value of the expected costs. Formally, we define the NPV for a solar tent dryer as follows:

$$\text{NPV} = \sum_{t=1}^T (R_t - C_t)(1+r)^{-t} - F_0 \quad (1)$$

where T is the expected life of a solar tent dryer, R_t is the expected revenue associated with the use of the fish solar tent dryer at time t , C_t is the expected cost associated with the use of the fish solar tent dryer at time t , F_0 is the initial investment cost of a fish solar tent dryer, and r is the discount rate. A solar tent dryer is economically viable if the investment on the solar tent dryer yields a positive net present value. Theoretically, in a case where more than one investment projects are being assessed, a project with the highest positive NPV is selected for investment [2].

The investment decisions on solar tent dryers are subjected to uncertainty because they involve future cash flows. To account for uncertainty, we introduced risk analysis to NPV analysis. Risk implies that a given action has more than one possible outcome [14]. Therefore, we make use of the expected value of NPV, $E(\text{NPV})$, to capture the future uncertainty:

$$E(\text{NPV}) = \sum_{x \in X} \text{NPV}(X)P(X) \quad (2)$$

where x is a vector representing a scenario that is going to be analysed; each component in x represents the state of a random variable; X is the space of states, i.e. the set of all the possible x scenarios that result from the combinations of the random variables that are considered; $P(X)$ is the probability of the x scenarios; $\text{NPV}(X)$ is the obtained result to the NPV in the analysed x scenarios.

In our analysis, x stood for all the inputs into the computation of the net present value. Some of these inputs include initial cost of capital and maintenance cost, inflation rate, production costs, buying and selling prices of fish. This was conducted by incorporating their probability distributions into the computations of the expected net present values.

To conduct the risk analysis, the study employed Monte Carlo simulations technique. This is a computational algorithm that is designed to evaluate the variability or stochasticity of the variable inputs of the model [7]. This technique was chosen because it is currently regarded as the most powerful technique for cash flow analysis of investment projects [13]. A total of 10,000 simulations were conducted by using the Crystal Ball in Microsoft

Excel. The sensitivity of the probabilistic NPV was also conducted by assessing the contribution of the input variables to the variance of NPV as well as assessing the rank correlation between NPV and the input variables.

Data

The study appraised investment decisions on a solar tent dryer which was 15 m long and 8 m wide, and the drying racks were double decked. This dryer has a capacity of drying 850 kg of fresh fish per a drying cycle that is averagely equal to 3 days, and it was estimated that this dryer would dry 8500 kg of fresh fish in a year if used to full capacity. The average amount of fish to be dried was determined by assuming that the dryer will be used to full capacity in half of the months in a year and 78% of capacity during the lean seasons, and this is based on the observed changes from the baseline survey. The estimated cost of constructing this dryer was MK1, 513,805 (US\$3050), and its estimated lifespan is about 8 years with estimated annual maintenance cost of MK281,500 (US\$567).

Data on the cost of constructing a solar tent dryer were extracted from project records and people involved in constructing. Two-way costing recording system was used to avoid over estimation and underestimation of the data. This involved obtaining estimates from the workers (builders and other employed labours) about the materials they used and also asking the project supervisors to provide their planned budget for the construction of the fish solar tent dryer. Expert opinion was used to project the life span of a solar tent dryer and annual maintenance cost of the dryer. Monthly purchasing and selling price of fish were extracted from the baseline survey of the project, and these were used to estimate average prices and their standard deviations. Data on cost of capital (real interest rate), inflation and exchange rate were obtained from the World Development Indicators. Summary of the model inputs and their values is presented in Table 1.

Results

Estimated Probabilistic NPV

Table 2 presents the results of simulation analysis of the NPV of fish solar tent dryer.

The results in Table 2 show that the base net present value for investing in a solar tent dryer and using it for 8 years is estimated at MWK5,838,482.11 (about US\$11,762). The probabilistic NPV was more than double the base NPV that assumed 100% certainty in the input

Table 1 Model input variables and their distributions. *Source:* Authors' compilation

Variable input	Mean	Standard deviation	Minimum	Maximum	Distribution
Cost of capital	14.68%	4.68%			Normal
Inflation	14.83%	7.89%			Normal
Buying price (MWK/kg)	269	89			Normal
Selling price (MWK/kg)	1449	422			Normal
Other costs (MWK)	19,351	2464			Normal
Quantity of fresh fish (kg)	7559	983			Normal
Quantity of dry fish (kg)	1512	197			Normal
Initial cost of capital (MWK)	1,513,850		800,000	2,000,000	Triangular
Maintenance cost (MWK)	281,500		110,250	449,474	Triangular
Depreciation cost (MWK)			118,013	323,424	Triangular

Table 2 Estimated NPV for the fish solar tent dryer

Statistic	Forecast values
Base case (MWK)	5,838,482.11
Mean (MWK)	12,268,503.78
Median (MWK)	10,611,171.19
Standard deviation	56,832,363.34
Variance	3,229,917,522,721,880.00
Skewness	0.2688
Kurtosis	4.61
Coeff. of variation	4.63
Minimum (MWK)	– 323,405,323.56
Maximum (MWK)	381,819,532.42
Mean std. error	568,323.63

variables (US\$24,716). This may be as the result of the positive skewness of most of the input variables that have positive influence on NPV. The positive NPV and probabilistic NPV suggest that investments in solar tent dryers are profitable. The large standard errors and variances suggest that the investments in the dryer are risky though viable. The large standard errors may mainly be as the result of the changes in fish catches and prices across the year due to seasonality. During the warm season, the catches are very high, and the fish prices tend to be low. In contrast, during the cold season, the fish catches are lower resulting in increased selling prices and cost of buying the fish. When fish catches are very high, and prices are very low, use of solar tent dryers may be unprofitable due to very cheap low-quality competing products on the market. Use of solar dryers can therefore be more profitable if the selling prices of fish are stable, and this can be achieved if the fish is sold in super markets. The cumulative density functions (CDFs) for the probabilistic NPV presented in Figs. 2 and 3 support this.

The findings in Fig. 2 show that the probability of obtaining a positive NPV was 58%, while Fig. 3 shows that the probability that we will obtain the estimated probabilistic NPV that is equal or greater than the mean probabilistic NPV was 49%, while the probability that the investors will obtain the base NPV mean of MWK5,838,482.11 or more is 55%. These findings show that the probability of obtaining a positive NPV is greater than the probability of obtaining a negative NPV which will entail that the investments are not viable. There is also a sizeable probability that the estimated NPV or greater than that will be realised. As can be seen, the inclusion of risk analysis in our estimation makes the findings more informative than many studies in the subject of economic viability assessment. Our results suggest that limiting the economic viability to the base case may underestimate or overestimate the NPV depending on the distribution of input variables. Further to that indicating the likelihood of obtaining the estimated results would give investors more confidence in the investment. The probability of obtaining a positive NPV was 58%, and we found that NPV is highly

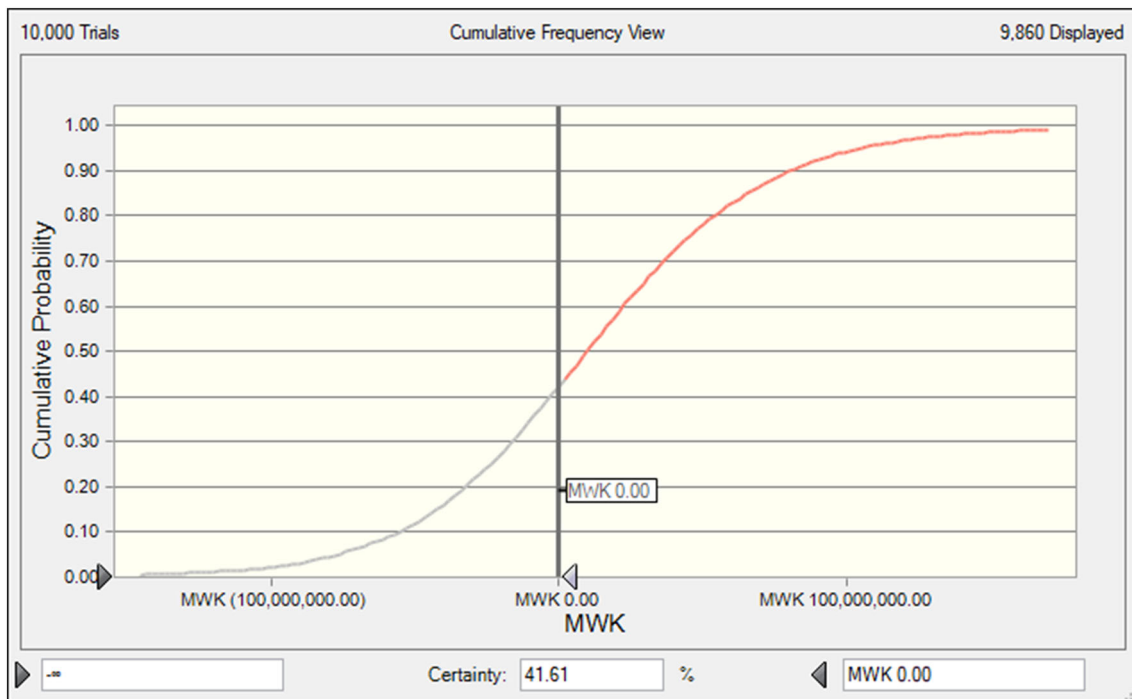


Fig. 2 Cumulative distribution of NPV showing the probability of obtaining a positive NPV

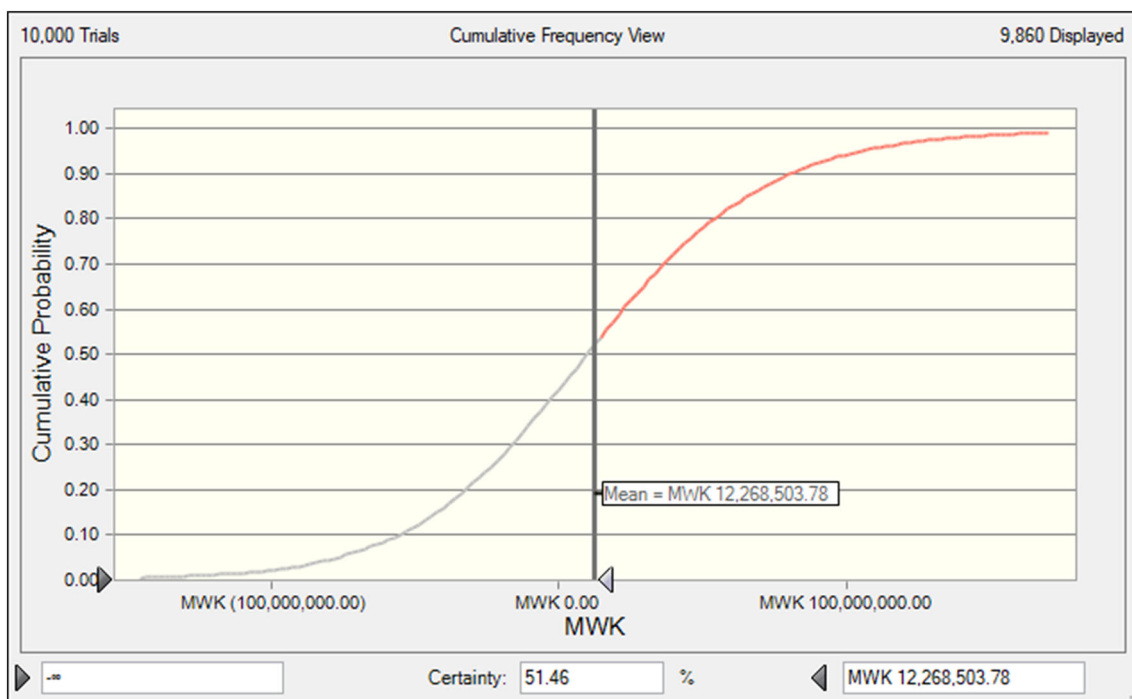


Fig. 3 Cumulative distribution of NPV showing the probability of getting the mean NPV

sensitive to total revenue and total cost. The positive NPV is an indication that the investment is highly profitable and the probability of making a profit is greater than the probability of making a loss.

Sensitivity Analysis

The results of the sensitivity analysis that assessed the contributions of the input parameters to the variance of the probabilistic NPV are presented in Fig. 4.

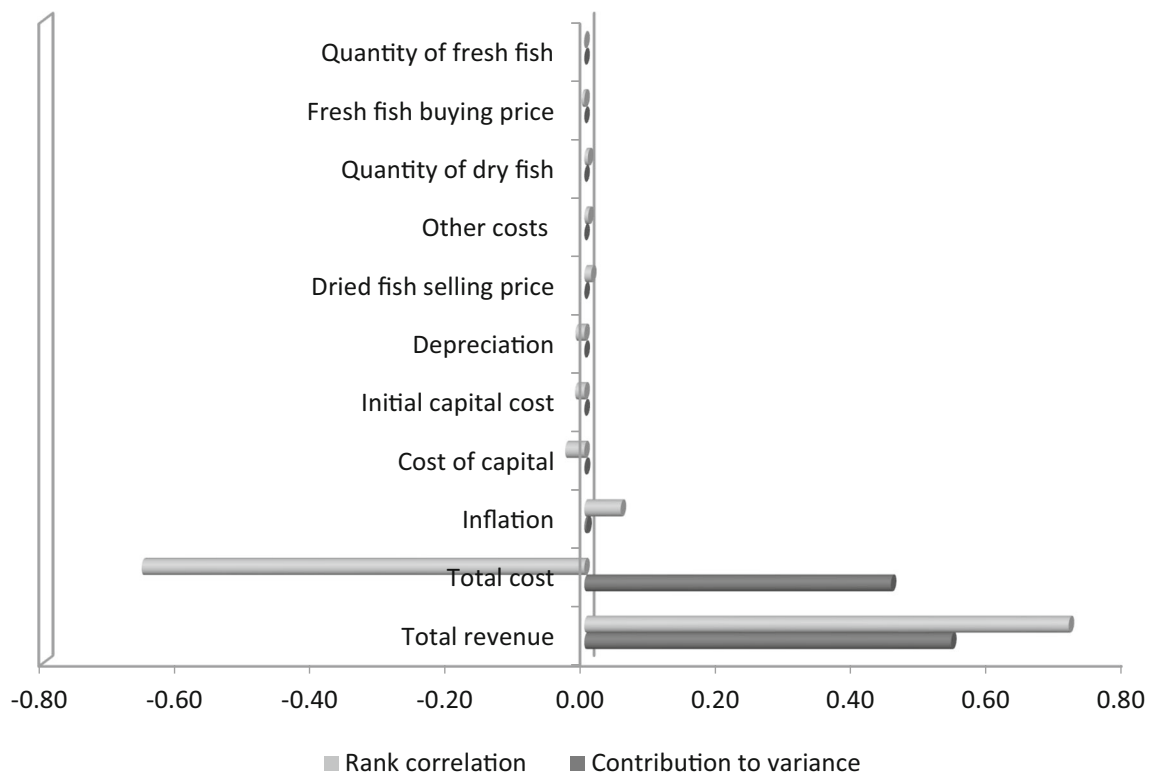


Fig. 4 Sensitivity analysis of NPV to variable inputs

From Fig. 4, it is seen that total revenue and total cost are the two inputs that substantially explain the changes in NPV. Other inputs with recognisable contributions are inflation and cost of capital. Inputs that have negative correlation with NPV are total operating cost and cost of capital, while total revenue and inflation have positive correlation with NPV. The positive correlation between inflation and NPV suggests that the effect of general price change though it will affect both cost and revenue will have a net positive effect on NPV.

The findings show that total revenue contributes largely and positively to the variance of NPV and it also has a large positive correlation coefficient with NPV, while total operating cost has a negative important correlation coefficient with NPV. Although total operating cost and total revenue have huge influences on the variance of NPV, their components such as prices and quantities seem not to have similar huge impacts on their own. These findings are suggesting that the combined effects are more important than the individual effects. However, policy implications should still consider the interventions on the components. Since one of the aims of designing the solar tent dryer was to increase fish supply without increasing fishing effort to sustain the fishery resources, these findings suggest efforts to increase fish quantity to increase the viability of the

technology should target improving fish handling techniques at the beach and on the lake to reduce fish postharvest losses before the fish enters the dryer. Additionally, revenue-enhancing activities should consider further value addition that will enable fish processors to sell solar dried fish at higher and stable prices in formal markets. Selling fish in such markets would reduce the risk on the viability of the technology as well as increase the level of viability. Presently, the fish processors that are selling solar dried fish in the formal markets are selling fish at more than double the price on local markets.

The conclusions that are derived from this study should recognise the following set of limitations: firstly, we conducted our analysis on a particular size of a solar dryer. We recognise that different sizes of solar dryers would imply different levels of profitability, but this was not done because we required to construct solar dryers of different sizes and assess their economic viability which was not possible due to resource constraints. Additionally, the technical performance of the solar dryer of the size we used was superior to other sizes. The other limitation is that our analysis is not providing information on the viability of other fish drying technologies, and thus, the findings from this study should be interpreted in absolute terms.

Conclusions

This study was conducted to assess the economic viability of large fish solar tent dryers and their associated risks, and we conclude that large fish solar tent dryers are an economically viable investment opportunity for fish processors and entrepreneurs. The viability can be enhanced by introducing fish processors to formal lucrative markets where solar dried fish are sold at stable and high prices. We therefore recommend that the technology should be promoted and that the promotion should include value adding activities such as packaging to improve access to formal lucrative markets.

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Author Contributions Statement LC supervised the work, analysed the data, drafted the manuscript, and reviewed the manuscript; CC collected the data, analysed the data, drafted the manuscript, and reviewed the manuscript; PK supervised the manuscript and reviewed the manuscript.

Compliance with Ethical Standards

Conflict of interest One author reports grants from International Development Research Center, during the conduct of the study. Other authors have nothing to disclose.

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References

- Affognon H, Mutungi C, Sanginga P, Borgemeister C (2015) Unpacking postharvest losses in sub-Saharan Africa: a meta-analysis. *World Dev* 66:49–68
- Awomewe FA, Olawale O, Ogundele H (2008) The importance of the payback method in capital budgeting decision. *MBA thesis*, Blekinge Institute of Technology school of Management
- Ayamga M, Yeboah RWN, Ayambila SN (2016) An analysis of household farm investment decisions under varying land tenure arrangements in Ghana. *J Agric Rural Dev Trop* 117(1):21–34
- Banda J, Katundu M, Chiwaula L, Kanyerere G, Ngochera M, Kamtambe K (2017) Nutritional, microbial and sensory quality of solar tent dried (Samva Nyengo) and open sun dried *Copadichromis virginalis*-Utaka (Pisces:cichlidae). *Int J Mar Sci* 7(11):96–101
- Baradey Y, Hawlader M, Ismail A, Hrairi F, Rapi M (2016) Solar drying of fruits and vegetables. *Int J Recent Dev En Technol* 5(1):6
- Brealey R, Myers S, Allen F Principles of corporate finance, 7th edn. McGraw Hill, Boston
- Dhiwaha EM (2010) Solar dryer for fish and vegetables. Shri AMM Murugappa Chettiar Research Centre, Taramani
- Doe P, Ahmed M, Muslemuddin M, Sachithanathan K (1977) A polythene tent dryer for improved sun drying of fish. *Food Technol Aust* 29:437–441
- El-Shiantry M, Müller J, Mühlbauer W (1991) Drying fruits and vegetables with solar energy in Egypt. *AMA* 22(4):61–64
- FAO (2008) Malawi fisheries and aquaculture profile. Food and Agriculture Organisation of the United Nations, Rome
- FAO (2010) Malawi fisheries and aquaculture Profile. Food and Agriculture Organisation of the United Nations, Rome
- Ihli JA, Musshoff O (2013) Investment behavior of Ugandan smallholder farmers: an experimental analysis. *Global Food Discussion Papers*. George-August-University of Göttingen, Göttingen
- Letcher RA (2003) A method for assessing the importance of farm level capital investment decisions in the analysis of water reforms. *Integrated Catchment Assessment and Management (iCAM) Centre*, Australian National University, Australia
- Luban F (2002) An integrated investment decision analysis procedure combining simulation and utility theory. *Eur Res Stud* V(1–2):23–36
- Magni CA (2009) Investment decisions, net present value and bounded rationality. *Quant Finance* 9(8):967–979
- Ogali EL, Eyo AA (1996) Evaluation of the Effectiveness of box-type Solar dryer in drying fresh water fish in Kainji Lake area. National Institute of Fresh Fisheries Research, New Bussa
- World Bank (2011) Missing food: the case of post-harvest grain losses in sub-Saharan Africa. The International Bank for Reconstruction and Development, The World Bank, Washington, DC

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