Pakistan Journal of Social Sciences 8 (1): 13-22, 2011
ISSN: 1683-8831

Does Technology Adoption Reduce Risks for Smallholder Farmers in Cameroon?

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Abstract: In sub-Saharan Africa where populations grow faster than the economy, new and improved agricultural technology can potentially reduce consumption and income-risks of smallholder farmers. This position is generally accepted within scholarly literature and experts often conclude that risk exposed farmers, who are better-off and less risk averse, adopt new technology faster than the very poor. This contribution discloses a comparative case study, analyzing a random sample of Cameroonian smallholder farmers who were offered to adopt fish farming by a non-profit non-government organization. Results indicate deficiencies in targeting risk-exposed farmers. Also, the needs and measures for the adoption of technology and to adapt innovative technologies to the specific needs and farming systems for optimizing risk reduction is explained. The need for impact assessments as a prerequisite for avoiding poor households to be pushed deeper into poverty due to technology adoption is also discussed.

Key words: Technology adoption, fish farming, risk reduction, smallholder farmers, Cameroon, prerequisite

INTRODUCTION

The importance of technological innovations and the empirical evidence on the impacts of adoption for global economic and social development are overwhelming. For countries that economically heavily depend on agriculture, the adoption of improved agricultural technologies has productivity-increasing potentials that can enhance long term economic growth (Doss, 2006). Agriculture is still a major source of employment and income in many developing countries. Improved agricultural technologies therefore have their greatest impact potentials in developing countries. However, in most developing countries, the adoption of improved technological innovations is often constrained by societal dynamic patterns. At the same time, technology adoption affects the distribution of wealth and income in adopting countries (Feder *et al*., 1985). This has been the case with improved agricultural technologies.

The introduction of improved agricultural technologies into developing countries began with the so called Green Revolution in the mid 20th Century. Following a series of bad agricultural years that precipitated a famine in the mid 1960s (particularly in Asia), the need to adopt High Yielding Varieties (HYV) from other parts of the world became a widely accepted policy and production change. The first results with miracle wheat were very impressive. Within 5 years, the adoption of improved wheat varieties shifted India from a net importer to self-sufficiency (Freebairn, 1995). The early successes with wheat led to the development and dissemination of improved agricultural technologies in different subsectors. Traditionally, international and national research institutes have been the prime forces behind developing improved agricultural technologies in developing countries. However, nonprofit organizations seem to have been the major actors in the dissemination of these technologies to the end users, particularly to smallholder farmers in developing countries (Balgah *et al*., 2010).

The Green Revolution prompted a growing body of literature on technology adoption. Although, empirical results are often positive, there are also opposite findings. Khush (1999) for example concludes that green revolution technologies have led to dramatic improvements in world food production and stresses that these technologies will be essential to meet the challenge of feeding eight billion people in the world by 2020. Evenson and Gollin (2003) in their analysis of productivity impacts of international agricultural research centers in developing countries between 1966 and 2000 conclude that the modern varieties contributed to large increases in crop production, even if

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productivity gains have been uneven across crops and regions. Consumers generally benefited from declines in food prices while farmers benefited only where cost reductions exceeded price reductions (Evenson and Gollin, 2003). Thus there can be differential impacts of innovative technologies between consumers and producers. This is a critical issue for smallholder farmers, who are usually producers and consumers at the same time and most often invest scarce resources in modern technology adoption. A review of over 300 studies on the green revolution technologies published between 1970-1989 by Freebairn (1995) shows that about 80% of the studies with conclusions on distributional effects of adopted new technology found increased inequality both at farm and regional levels. Clearly, this evidence diverges from the position of Khush (1999) while confirming some of the contentions of Evenson and Gollin (2003). Thus, the eminent divergence in the literature has been a strong motivation for continuous research in the domain of technology adoption at macro, meso and micro levels.

This study aims at contributing to better understanding the effects of technology adoption on risk reduction for smallholder farmers in developing countries. Using a micro level case study approach, it comparatively assesses the levels of income and consumption risks for adopters and non-adopters of integrated fish farming technologies in North West Cameroon. More specifically, it measures the contribution of technology adoption with regard to reducing overall vulnerability as a proxy for the actual impact of technology adoption. Assessing technological impacts provides justification for termination, adjustment or further dissemination. This is essential to avoid technological failure and unpleasant benefits on adopters, ex-post or ex-ante. The results are expected to impact the fish farming policy at regional and national level so as to allow adopters reap maximum benefits by adopting the technology. Further research trends will also be suggested.

Smallholder agriculture and technology adoption

A brief review of literature: Smallholder agriculture was not central to development economics even up to the 1950s as the highly influential model belittled this sector as a labor reserve from which workers could be drawn and shifted to the growing industrial and service sectors. This view however changed from the 1960s-1980s as it became evident that smallholder agriculture was instrumental in the success of the green revolution (Kydd, 2002). The 1990s saw a strategic positioning of smallholder agriculture within the so called livelihoods approach. Employment diversification was understood as an important livelihood strategy and smallholder agriculture was recognized as the main platform for rural poverty reduction (DFID, 1999; Ellis, 2000). Promoting innovative agricultural technologies for smallholders was accepted as an efficient and equitable approach to promote economic growth. Smallholders were more efficient in the allocation and use of resources (compared for example to commercial farms) and their promotion enhanced equity as it increased returns on assets held by the poor and puts food and cash income directly into the hands of the poor (Kydd, 2002). The later part of the 20th century therefore witnessed increased development and testing of technologies appropriate to smallholder farmers. Reaching out to smallholder farmers was an important component of poverty alleviation programs.

The smallholder farming sector in developing countries depicts specific characteristics that must be carefully considered for successful technology transfer. Smallholder farm households derive a substantial share of their livelihood resources from agriculture (even if non-farm income is important) and utilize mainly family labor in the production process. Smallholder farmers cultivate generally less arable land than national averages. The land is divided in many plots and the farms are only partially integrated into the market (Ellis, 1988). Labor power is their principal asset (Barrett *et al*., 2008). Information asymmetry is common and this negatively affects technology adoption (Stiglitz, 1989). Crucially, the farm is an economic unit of production and consumption at the same time and farm decisions are often influenced by household objectives other than profit maximization. Risk and thus vulnerability reduction are important household and farm objectives. Thus risk-averse households with strong risk reduction objectives might show preference for short term security-enhancing technologies over higher incomes especially under conditions of uncertainty (Feder, 1980; Ellis, 1988; Purvis *et al*., 1995). Smallholder farmers exhibit differential ability to take on new production technologies that appear initially expensive.

This is because they fear severe welfare consequences if for instance shocks result in poor harvests (Dercon and Christiaensen, 2007). This implies that the initial higher input expenses add to the yield losses. Not surprising therefore, smallholder farming in many developing countries is still dominated by crop-livestock integrated systems (Wollmer, 1997) even if monoculture with high yielding varieties could be a better alternative with regard to income maximization. Also, social objectives demonstrated through reciprocal transactions in the so called moral community (Scott, 1977) or the economy of affection (Hyden, 1980) may be more important for households even at lower levels of production and consumption. These social objectives may influence technology adoption choices. Evidently, technology adoption by smallholder farmers requires a multi-stage procedure that understands the status quo and absorbs technologies into existing farming systems in a flexible manner. The new technology should support the farm household to meet its multiple objectives. An understanding of these elements is essential in the successful development, dissemination and adoption of technologies by small farmers in developing countries.

The development, dissemination and adoption of the Green Revolution technologies have led to a growing body of literature on technology adoption especially by small farmers. The largest portion of this literature has focused on the determinants of adoption and disadoption of improved technologies (Katz and Shapiro, 1986; Zeller *et al*., 1997; Morris and Vankatesh, 2000; Neill and Lee, 2001; Conley and Udry, 2001; Taludkar and Sontaki, 2005; Adeogun *et al*., 2008; Wetengere, 2009).

Neill and Lee (2001) for instance reveal that the successful introduction and adoption of maize-mucuna technologies in northern Honduras in the 1970s and 1980s was strongly influenced by its reduction of pre-harvest labor of 15-20% as compared to the traditional system. However by 1997, external factors (such as a growing market for cattle production), agronomic and biophysical factors (particularly the spread of the itchgrass Rottboellia cochinchinensis on farmers fields) and management factors (such as failure to reseed mucuna and inappropriate application of herbicides) were jointly responsible for the disadoption of maize-mucuna technologies. The technology was dropped at the rate of about 10% per annum in northern Honduras. This example clearly demonstrates how changing external factors can influence production technology. Wetengere (2009) indicates that age, sex, level of education, extension education, land size, income, family size, risk and profitability were positively correlated with the adoption of fish farming technologies in eastern Tanzania.

Although, some research is evident on the comparative analysis of different technological options appropriate to smallholder agriculture (Kang-Ombe *et al*., 2006; Ricker-Gilbert *et al*., 2009), the second largest bulk of this literature seems to be interested in the overall impact of technology adoption on food security, poverty alleviation, sustainable natural resource management and livelihoods (Brummett and Williams, 2000; Tidwell and Allan, 2001; Jamu *et al*., 2002; Prein, 2002; Brummett *et al*., 2008; Laxmilatha *et al*., 2009). Kang-Ombe *et al*. (2006) after conducting pond trials on the differential effects of organic manure on plankton abundance and growth of fish conclude that under the same conditions, the adoption of chicken manure for pond fertilization is a far better technological option, compared to cattle or pig alternatives. Ricker-Gilbert *et al*. (2009) report significant increases in yields for farmers using commercial fertilizers as compared to those accessing subsidized fertilizers in Malawi concluding that government should target farmers who lack access to commercial markets to improve the overall impact of its fertilizer subsidy program. Brummett and Williams (2000) discuss the constraints and potentials of adopting aquaculture technologies in African countries with specific reference to its food security increasing potentials. Laxmilatha *et al*. (2009) report how the successful adoption of mussel farming in north Kerala India led to a significant positive transformation of livelihoods especially for women farmers.

While less efforts have been endowed by researchers on understanding farmers behavior towards technology adoption under uncertain conditions (Feder, 1980; Feder *et al*., 1985; Purvis *et al*., 1995) even lesser energy has been dedicated to explaining the puzzles on how technology adoption enhances or reduces short and long term risks for adopters and the implications for policy. Exceptions include for example Doss (2006) with an extensive review of the limitations, challenges and opportunities for technology adoption and their implications for policy and reports of clinical nutritional studies such as Huang *et al*. (2006) and Virtanen *et al*. (2008). Even so, opinions remain divergent. For instance Virtanen *et al*. (2008) conclude that modest fish consumption reduces risks of contracting cardiovascular diseases and cancer while Huang *et al*. (2006) caution that the consumption of some fish might actually increase cancer risks, specifically due to organochlorine contaminants. Thus further research and clarification on the impacts of technologies on risks in necessary.

The literature on impacts of technology adoption often implicitly analyzes risk and vulnerability factors as independent variables. There is little scholarly evidence on these factors as dependent variables that can be significantly influenced by technology adoption. For example Zeller *et al*. (1997) report exposure to agro ecological risks as a major factor influencing the adoption of improved maize technologies in Malawi. Recent efforts of the World Bank have resulted in the development of a framework for risk and vulnerability assessments which is increasingly successfully applied in empirical case studies (Alwang and Siegel, 1999; Holzmann and Jorgensen, 1999, 2000; Holzmann *et al*., 2003; Chaudhuri *et al*., 2002; Skoufias and Quisumbing, 2004; Gunther and Harttgen, 2009). The increasing interest in environmental risk impact assessments has also generated a growing body of literature that examines the environmental risks associated with the introduction of specific technologies (Ramanathan, 2001; Ge and Innocent, 2008). Ge and Innocent (2008) for example suggest that for technologies to be successfully adopted by smallholder farmers in the Bamenda highlands of Cameroon, they should optimize agricultural production and increase income while mitigating climate change. From the theoretical discussion above, it can be deducted that integrated fish farming technologies currently promoted amongst smallholder farmers in the North West region of Cameroon should meet this triple objective. To evaluate whether this is the case in practice is one of the key aims of this study.

Aquaculture and fish farming

Trends and relevance for risk reduction in (sub Saharan) Africa: Fish is an important source of animal protein for households in developing countries. In fact, Africa is second to Asia with 17.4% of total animal intake as fish for the former compared to 25.7% for the latter (Brummett *et al.*, 2008). For Africa, this represents a current consumption of 7.7 kg/pers/year, down from 9 kg in the early 1980s due to rapid population growth and stagnating production. To meet current demand, Africa imports a total of about 4.2 million tons of fishery products making the region a net importer of fish (FAO, 2005b). But the potential of African aquaculture has been reported. Kapetsky (1995) for example estimates that available water and land resources in African countries can produce a total of 1.5 thousand million tons of fish per year. This estimate is higher for example, compared to the total global production of 51 million tons in 2003 (FAO, 2005a). The potential for fish farming in Africa is therefore enormous and integrated fish farming technologies stand to benefit mostly the over 70% of Africans involved in small-scale subsistence agriculture (World Bank, 2000). In sub-Saharan Africa in particular where poverty incidence is highest, an estimated 37% of the land surface is suitable for small scale, artisanal fish farming. If this potential is realized it could have substantial impacts on food security and poverty alleviation especially for the poor (Brummett *et al.*, 2008).

Like many other sub-Saharan African countries, Cameroon is a net importer of fish. For example the net import of fresh water fish products remained stable between 1998 and 2001 (around US$30 million) while exports dropped from US$ 2.6 million to less than half a million within the same period (FAO, 2003). Meanwhile almost 50% of its animal protein depends on fish sources. Fourteen other African countries depend on fish for over 30% of their animal protein (FAO, 2005b). The potentials for sub-Saharan African aquaculture, coupled with the recorded successes in Asia (Prein, 2002) and the depletion of natural fisheries stocks (Tidwell and Allan, 2001) led to the promotion and adoption of integrated small scale fish farming in most African countries with varying degrees of success. Jamu *et al.* (2002) find that integrating aquaculture into agricultural systems increased whole farm productivity, household income and farm resilience to drought and improved household food security and the nutritional status of under-five children for adopting households in Malawi. Similar trends and high rates of adoption of fish farming technologies have been reported for other African countries such as Nigeria and Tanzania (Wetengere, 2009). This study focuses on an assessment of the impacts of adopting fish farming technologies in North West Cameroon. As will be shown in the results, technology adoption might have differential impacts on reducing consumption and income risks for households in different countries.

MATERIALS AND METHODS

Empirical research was carried out in the North West Region (NWR) of Cameroon. It is one of the most populated regions in the country and counts about two million inhabitants (11% of total population) who live predominantly (80%) in rural areas. The population growth rate in the region (4.5%) is higher than the national average of 3.3% (Ge and Innocent, 2008). The economy of the region strongly depends on agriculture, over 90% of which is produced in smallholder, fragmented, mixed cropped farms mainly for subsistence. Fish farming is one of the multiple technologies that have been adopted by some small-scale farmers in the region. An estimated 80% of households depend on fish for >50% of their animal protein dietary needs. Maritime fishing is conspicuously absent and inland fishing is limited. Thus, fish production in the region remains pushed by aquaculture. Fish species cultivated by farmers include tilapia, clarias and occasionally carp. The region counts some 1,365 fish farmers owning 1,709 ponds covering a total surface area of 350,481 m^2. These farmers are technically supported by government and Non Governmental Organizations (NGOs) extension services and five fish breeding stations (Provincial Service of Fisheries, 2003).

The villages selected for the research benefited from extension services of a Rural Development Non Governmental Organization (RDNGO) known as the Presbyterian Rural Training Center (PTRC) in Bamenda, NWR of Cameroon. The integrated small-scale fish farming project did not maintain baseline information on beneficiaries. In the absence of panel data only cross sectional data collection ex-post was possible. A standardized questionnaire was used to collect quantitative data on the socioeconomic characteristics and resource use patterns of adopting and non-adopting households. A second structured questionnaire was employed to collect data on the income structures to assess differences in income structures.

The sampling unit for this survey was the household. The population was drawn from fish farming and matching non-fish farming households in the same villages. A stratified random sample of ten villages was surveyed. Villages with fairly good access to the market as well as villages which are virtually inaccessible in some periods of the year were included in the sample to avoid selection bias.

The selection also captured differences in altitude. Because the research region displays a high variation in altitude and market access from one village to another, these factors were used to stratify the sample villages. This was aimed at reducing sampling bias and improving the regional representativeness of the fish farming population in the sample.

A standardized questionnaire (Henry *et al*., 2000, 2003) was used to collect socioeconomic data from a random sample of 152 households (60 adopters and 92 non-adopters) for comparative assessment of relative risks and Natural Resource Management (NRM) patterns. A list provided by the PRTC allowed for random sampling of fish farmers. The matching non-adopters were randomly drawn from a list established with the help of local village authorities.

On top, a sub-sample of 60 households (30 households from each of the two household types) provided information on household income and expenditures for the year 2003. Selection by the researcher was based on the household's ability and willingness to engage in a recall process.

This selection took place during the first survey round. The second round was devoted to a comparative analysis of household incomes and expenditures, only with the selected 60 households. Both the household head and his or her spouse were present and participated actively in the recall process. Recent research (Fisher *et al*., 2010) suggests that this approach reduces data collection errors.

The non-selected households were not involved in the second survey round but participated in the summative feedback workshop at the end of the research period. Primary data was collected in North West Cameroon between September 1, 2003 and February 28, 2004. Both descriptive statistics and econometric analysis were performed.

RESULTS AND DISCUSSION

Natural resource management indicators: Table 1 shows comparative descriptive statistics on selected natural resource management indicators. As demonstrated, the adoption of integrated fish farming significantly enhanced a number of natural resource practices amongst adopters compared to non-adopters. For example, over 90% of adopters compared to 55% of non-adopters planted at least one tree or participated in watershed management activities in the empirical recall year.

Similar trends were observed with the use of organic manures. These results were expected as the integrated fish farming technological package encompasses a watershed protection component and emphasizes the use of organic manures in pond fertilization. Soil conservation practices were quite high amongst both groups of households. This high practice is attributable to the generally hilly nature of the terrain and to other improved crop production technologies (Cassava, maize, yam) which are disseminated to all interested members in the research communities with soil conservation as a vital technique.

Socio-economic analysis of adopters and non-adopters of fish farming: Human capital was assessed based on household head's literacy and the household labour force. Although, the literacy rate (assessed as a cumulative percentage of those who completed primary school and above) was generally lower than the national average of 94% for 2002 (WRI, 2006), a significantly higher proportion of adopting household heads (72%) could read in comparison to non-adopters (53%). This supports previous empirical evidence (Zeller *et al*., 1997) that education or literacy level is positively correlated with technology adoption. Adopting households are slightly larger which could indicate either higher vulnerability or more labour force to account for additional income creating activities. The mean of adopter households is 5.3 persons as compared to 4.6 for non-adopters and 4.9 for all sampled households. As fish farming is labour intensive, it seems to suggest that larger families can more easily incorporate and maintain fish activities within their existing farming system. This difference is statistically significant.

Table 1: Comparative analysis of natural resource management indicators

	Level of adoption (%)		
Variables	Adopters	Non-adopters	X^2
Tree planting/water shed management	93	55	0.000
Use of inorganic fertilizers	37	26	0.002
Soil conservation techniques	88	91	0.250

Own survey data

On annual food security, <20% of households (18.6% of fish farmers and 18.7% on non-adopters) acknowledged having access to sufficient food at all times within the year. Nevertheless, with a mean of 5.4 meals per 2 days or close to three meals a day, the issue of food security as a serious problem in the research villages could be traced to the hunger periods between the months of March and May. The consumption of luxury foods (this term is attributed in the region to meat, fish, eggs and tea) was also found to be quite high with a mean of 3 times week^{-1} for fish farmers and two for non fish farmers (with a range from 0-6). The difference is statistically significant at the 1% level. However because none of the fish farmers consumed their own fish within the research period as a luxury meal, the consumption of luxury meals by adopters is difficultly attributable to the impact of the service delivery. The number of inferior meals per week was found to be the same: two per week for both household types. Regarding dwelling, 90% of all households own the houses in which they live while the remaining households mostly live in rented houses or houses offered by relatives. House ownership was found to be very important in the research region. In general, most households have permanent dwellings with walls constructed out of sun-dried bricks and roofed with Zinc. The generally good quality housing and household ownership of permanent dwellings indicate the high utility that households derive from housing in a region where a man's worth is depicted in the village through ownership of a house (Interestingly, the interviews with villagers revealed that owning a house, irrespective of the quality is an important social indicator of wellbeing with the quality of housing differentiating the better-off from the poor and the less poor).

An assessment of household assets indicated significant differences between the values of assets for the two household types (Table 2). Fish farming households generally hold more high value assets than non-adopters. Taking the value of livestock as an example, the total value for fish farming households (about 200 US$) is almost double that of non-adopters. It is also worth mentioning that the expenses on clothing and foot wear differ, a key indicator used in the poverty assessment tool as a proxy for household poverty level. It is the bench mark indicator used in calculating the poverty index. Past studies (Minten and Zeller, 2000) have shown that the proportion of clothing expenditure in household budgets remains stable, around 5-10% of the total expenses and increases proportionately with household expenditures. Also clothing, unlike food commodities usually requires the purchase of a finished garment or the materials to make the garment and can easily be recalled by households compared to other goods. Fish keeping households were found to have significantly higher per capita clothing and foot wear expenditures than non beneficiary households. Because household expenditures on clothing tend to increase with household incomes, this difference suggests that for fish households to spend more on clothing and foot wear per capita, they are most likely to have higher incomes than non-fish farming households. The standard deviations signal wide differences between households of the same type, even if the mean expenditures are higher. This means that there can be fish farming households who spend less on clothing and foot wear per capita compared to non fish farming households.

Table 2: Comparative analysis of values of some selected household assets

Variables	Household type	Mean±SD	p-value
Value of livestock assets in FCFA	Adopters	92,758±102,827	0.009
	Non-adopters	50,887±89,512	
Land size (ha)	Adopters	5.991±4.7	0.011
	Non-adopters	4.093±3.8	
Value of household equipment in FCFA	Adopters	35,212±70,905	0.031
	Non-adopters	15,125±42,259	
Family size	Adopters	5.3±3.0	0.077
	Non-adopters	4.6±2.2	
Value of transport facilities in FCFA	Adopters	14,390±48,737	0.516
	Non-adopters	20,592±6,196	
Per capita expenditure on clothing and footwear in FCFA	Adopters	24,881±11,240	0.001
	Non-adopters	19,115±10,167	

Own survey data analysis. Average annual exchange rate: 1 USD = 608 FCFA

Table 3 shows the financial analysis of adopting and non-adopting households. Again, this table maintains the consistent trend of higher figures for fish farming households compared to non fish farmers. The socioeconomic analysis presented generally shows higher values for income indicators for fish farming households, although the patterns are generally lower compared to national standards. For instance, the gross income per capita for fish farmers (94,171 FCFA or 154 US$) and non-fish farmers, (95,650 FCFA or 157 US$) poorly compare with the national gross national income per capita of 550 US$ in 2002 (World Bank, 2004). This suggests that all the households are poor and vulnerable to risks.

As already mentioned, the descriptive statistics generally indicate that adopters are better-off compared to non-adopters although, most of the differences are statistically insignificant. Yet it is not clear whether this trend will remain the same when the different variables flow into a single poverty index or if any differences observed can be attributed to the impact of technology adoption. In the absence of panel data, two further analytical steps were carried out. Pulling the variables into a household poverty index and assessing its distribution

Table 3: Comparative analysis of income structures by household types

In FCFA	Household type	Mean±SD	p-value
Net farm cash income	Adopters	205,217±146,995	0.135
	Non-adopters	159,233±77,4820	
Total non cash income	Adopters	174,695±89,7610	0.850
	Non-adopters	170,419±84,6270	
Total non farm income	Adopters	119,197±122,843	0.780
	Non-adopters	110,340±121,317	
Gross income	Adopters	499,108±231,187	0.306
	Non-adopters	439,992±211,364	
Gross margin	Adopters	445,254±199,330	0.300
	Non-adopters	392,923±187,902	

Own data analysis. Average annual exchange rate: 1 USD = 608 FCFA; The gross margin is defined as gross household income minus total variable costs

in the 2 groups by performing econometric analysis and assessing the direct contribution of the adopted technology to the total household gross revenue and livestock assets as a proxy for its contribution to risk reduction for adopters.

Econometric analysis: The Principal Component Analysis (PCA) was used to develop the poverty index. PCA isolates and measures the poverty component embedded in the various poverty variables to create a household-specific poverty score or index. The first step consists to run bivariate analysis in order to measure the correlations between ordinal and ratio-scale variables and the bench mark indicator, per capita expenditure on clothing and foot wear (Henry *et al*., 2000, 2003). All variables correlating with the bench mark indicator (significance better than 10%) were selected to be used later in computing a poverty index through the application of the PCA. The main idea is to formulate a new variable X* which is a linear combination of the original indicators that accounts for the maximum of the total variance in the original indicators. The index of poverty therefore takes the form:

$$X^* = w1X1+w2X2+w3X3....+wnXn \quad (1)$$

Where the weights (wn) are specified such that X* accounts for the maximum variances in Xn. According to Henry *et al.* (2003), amongst other conditions, an accepted model should develop poverty indices with a mean of zero and a standard deviation of one. The model meets this requirement (mean 0; standard deviation 1.01; range -1.25-4.25). Using the poverty index, non-adopters were first ranked and grouped into three terciles that is the lowest 33% of households were categorized as the highest risk group, the middle moderate risk and the last as the just at risk (Henry *et al*., 2000, 2003; Irungu, 2002). The middle tercile for non-adopters provided the cut-off points for the three groups. Based on these cut-off points, adopting households were also grouped

Table 4: Distribution of risk terciles for adopters and non-adopters

Household category	Lowest tercile highest risk (%)	Middle tercile less risk (%)	Upper tercile just at risk (%)	Cumulative (%)
Adopters	18	22	60	100
Non-adopters	33	33	34	100

Own data analysis

accordingly. The use of the poverty groupings of non-adopting households insures that they are equally represented in all groups while adopters would vary according to the level of poverty relative to that of the population. Table 4 shows the results. Adopters are significantly better-off compared to non-adopters as 60% of the adopters are just at risk, compared to 34% of non-adopters in the same category. A higher percent of non-adopters (66%) are highly exposed to risks. However, this does not answer the question as to whether these differences might have been significantly influenced by the adoption of integrated fish farming.

To tackle this issue, researchers compare the gross income of the fish farming enterprise to the average income of fish farming households and to the value of livestock assets. If this contribution is substantial, then we can attribute the difference between the household types to fish farming technology adoption. Contrary results will indicate a deficiency in initial targeting of the poorest by the nonprofit (service delivery) non-governmental organization.

The results show that the mean total annual income from fish farming of 3,520 FCFA (5.8 US$) contributed <1% to the total household annual gross income of 499,108 FCFA (820 US$) and <4% to the value of livestock assets for adopting households. Put differently although, the gross income for adopters is generally higher than for non-adopters, this has not been influenced in any significant way by the income from the fish enterprise. Thus adopting households were already better-off than the average households in the targeted communities before project intervention. Its insignificant contribution to livestock assets means that it does not play a significant role in buffering household shocks. This indicates a pitfall in targeting the poorest within the intervention regions and risk exposure for adopting households.

The shortcoming of the nonprofit organization is probably a consequence of improper technology dissemination orchestrated by strongly influential donor policies (Brummett *et al*., 2008) (at the time of this research, the main funder for the organization (Bread for the World-Germany) was satisfied with output indicators such as the number of ponds constructed, assuming that all people in the intervention communities are poor. Although, relative poverty assessments prior to program implementation could have improved targeting and outreach performance, this will be contingent on the willingness of the funders to increase funding. As such, any change in the present mode of targeting and service delivery will need the consent of the funder) while the inability of fish farming to reduce future risks is a probable explanation for why risk averse farmers may not have adopted this technology. Nevertheless, over 80% of the harvested fish was either consumed and/or shared with friends and relatives. This indicates that at least technology adoption has social impacts within the moral community.

CONCLUSION

This study has examined the impact of technology adoption on risk reduction for smallholder farmers in Cameroon, proxied by consumption and income. Using integrated fish farming technologies, it has been proven that short term food security (measured on the number of meals per day) is not significantly different between adopters and non-adopters. However, over 80% of fish harvested by adopting households was consumed by the household and other community members.

This signals the importance that adopting fish farming technologies can have on household animal protein intake and strengthening social capital. The average gross revenue of adopters and non-adopters is <10% of the national Purchasing Power Parity and <1 US$ a day. Thus, both adopters and non-adopters are currently poor and vulnerable to risks. However, a significant share of fish farming adopters are less risk exposed compared to non-adopters, although this difference cannot be attributed to technology adoption, considering that it contributes <4% to the household livestock assets and 1% of gross income. Adopting fish farming enhanced sustainable natural resource management by promoting tree planting or water catchment activities and significantly increasing the use of organic fertilizers amongst adopters. An overall assessment shows that adopting fish farming did not have a significant impact on farmers' risk reduction in the research area.

RECOMMENDATIONS

The results have a number of policy implications. First, the specific behavior of risk-exposed households needs to be considered in technology adoption. Secondly, there is a need for impact assessments of different technologies, once they are adopted by farmers. This can provide important insights for policy makers to make adjustments that avoid total failure of modern technologies. Thirdly, technology transfer does not always yield the expected results. Although, fish farming is reported to be having strong impacts on household incomes in Asian and some African countries, such results seem to be illusive in the Cameroonian case. Future research should therefore focus on understanding why imported (fish farming) technologies have not yielded the same results in Cameroon as in other regions and why farmers continue to adopt this technology, in spite of its insignificant contribution to overall household risk reduction.

In the meantime, fish farming promotion agencies in the research region should embark on the search for new options that could render fish farming more productive in order to assert a more important place in household risk reduction for smallholder farmers. Such options should be flexible, productive, attractive and adaptable enough to be contained within smallholder farming systems.

This can be supported by a comparative analysis of fish farming and other improved agricultural technologies adopted by smallholder farmers. Otherwise, what might likely be observed in the near future will be high rates of disadoption as farmers in North West Cameroon rationally choose and maintain farm enterprises assessed to have high potentials for short and long term risk reduction for adopting households.

ACKNOWLEDGEMENT

The researchers would like to thank the Evangelischer Entwicklungsdienst (EED) in Bonn Germany for financially supporting this research.

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