Stimulating the Market for Pico-hydro in Ecuador

Simon D.B. Taylor, Dr. Manuel Fuentes, Dr. John Green, Dr. Kavita Rai

IT Power, Grove House, Lutyens Close, Chineham, Hampshire, RG24 8AG, UK

Introduction

Providing modern energy services in remote rural areas is often costly and difficult to achieve. However, the availability of reliable energy supplies in rural areas is one of the key components required to help developing countries to meet many of the Millennium Development Goals. Rural communities around the world deserve the opportunity to benefit from their abundant natural resources and have access to modern energy supplies.

Pico-hydro (very small hydropower units suitable for a single household or a small group of households) is a comparatively cheap option and is able to be used by millions of people who presently live in un-electrified areas of developing countries where a hydro resource exists. It is becoming a mature technology which should now be considered as part of the menu of alternatives to grid extension, diesel generators, solar PV systems and other energy systems presently being used in rural areas. In comparison to these options, pico-hydro can be installed at a lower cost for the same energy output and in the markets where it has become established, subsidies have not been required. However, there is a need for programmes to support the emergence of pico-hydro markets in developing countries.

This project has undertaken the groundwork to establish this type of development within Ecuador, by undertaking a market assessment for pico-hydro in the Andean region, developing technical capacity to install and maintain pico-hydro systems at demonstration sites (see Figure 1) and helping a small group of businesses to see the commercial opportunities arising from the sale of pico-hydro systems within the country.

Figure1 – Pico-hydro installed in Ecuador for family use

A sales and commercial infrastructure for pico-hydro may emerge within Ecuador as a result of these activities. However, further training courses on installation and maintenance for potential pico-hydro dealers in other regions and an awareness raising promotion campaign would help this to be achieved. In addition, the establishment of a system of monitoring, quality assurance and certification for pico-hydro equipment will also help to ensure that the benefits of using reliable, good quality equipment are made evident to purchasers. If these activities are supported, pico-hydro will be able to play a significant role in helping to improve the lives of those people around the world who would otherwise not have access to electricity and the educational, economic and social benefits it can bring if properly developed.

1. Background to pico-hydro technology

A pico-hydro unit typically has a capacity of between 200-1000 Watts of electrical power but the term ‘pico-hydro’ can include systems up to 5kW. A ‘low-head’ propeller or ‘medium-head’ turgo-type turbine (see Figures 2 and 3) are used for domestic electricity applications such as lighting, TV/radio and battery-charging. The units are small and cheap (in the range of US$25 for 200 Watts up to US$580 for 1,000 Watts) and are typically owned, installed and utilised by a single family, hence their commonly used name of ‘family-hydro’.

Figure2 – Vietnamese 200 W low-head pico-hydro ‘propeller’ unit in the Philippines

Figure3 – Vietnamese 200 W medium-head pico-hydro ‘turgo’ unit in Ecuador

The different types of technologies used for pico-hydro power throughout the world cover a range of turbine types and power outputs, applicable to different heads:

- Tiny pelton wheels (‘Peltric’ sets) are being promoted in Nepal for sites with 20-50m head – only a hose-pipe is required for a penstock. Many hundreds have been installed and there are dozens of manufacturers.
- In the Philippines, tiny crossflow turbines (‘Fireflies’) are being trialled at 5-20m head and there is similar development in Colombia.
- In the USA, Canada and Australia, a few companies offer a variation on the turgo-turbine for medium and high-head sites, principally to serve remote off-grid dwellings. Also, countries in Europe have developed small pelton turbines for powering remote Alpine lodges.
- China and Vietnam have had the greatest dissemination of low-head propeller turbines, suitable for only 1-2m head (sometimes called ‘standing’ turbines) and tiny turgo turbines for 5-11m head (or ‘sitting’ turbines).

Globally, low to medium-head sites (1.3 to about 10 metres) are by far the most widespread, available from irrigation canals as well as streams, and both in hilly and plain areas. These sites do not require a long supply pipe to bring water from further up the hill, and low-head pico-hydro schemes simply employ a compact ‘flume’ (for conveying the water into the unit) and a short draft tube (for creating the head) as an integral part of the turbine. Higher head sites have been developed in areas where the topography lends itself to this type of development, such as in countries of the Himalayas.

In Vietnam and China, 200-300 W pico-hydro technology has become particularly widely available at an affordable cost of $25-50 per installed unit. Pico-hydro units have also been sold in other parts of South and SE Asia, South and North America, Europe, Australia and the Pacific Islands. There has been only minor uptake of the low-head technology in Africa to date [Whalan, 2003] but there remains a massive unexploited potential throughout South-East Asia, South America, the Indian sub-continent as well as in Africa.

2. Pico-hydro experience in Vietnam

In Vietnam, the number of households without grid power was 4.8 million in 2000 and the number could still be 3 million by 2010 [ASTAE, 2000]. Many households in the country have chosen off-grid solutions to obtain electricity, and due to the favourable hydro resources and the presence of cheap pico-hydro turbines, the country has the highest use of pico-hydro in the world. Even some grid connected consumers choose pico-hydro as a back-up because the grid is unreliable. Approximately 50% of the population live in rural areas where houses are close to a stream or irrigation canal, and about 1.56 million of these households are estimated to have direct access to a water course [RERC, 2003]. Vietnam has therefore seen pico-hydro technology naturally finding its market in areas where other hydro development or grid extension work is not happening due to either remoteness or low local affordability.

2.1 Vietnam market characteristics

It is estimated that approximately 120,000 units have been installed in Vietnam since the late 1980s providing electricity to approximately 130,000 households [Institute of Energy in Vietnam, 1996], most in the north-west corner near the border with China. However, only about 40%, or less than 50,000 of these systems, are likely to be still operational. The main reasons for the high failure rates are the low quality and durability of the turbines on sale.

In summary, 90% of the market is being supplied by low-quality, cheap (approximately US$20) pico-hydro equipment imported from China with a rated capacity of 300 W, but actual power of 100 W. Private Vietnamese workshops have copied the Chinese equipment and their quality is even lower than that of the Chinese original. But better quality local units ('MTD series' of the Renewable Energy Research Centre (RERC) at the Hanoi University of Technology and 'Hydrotec' of the Institute of Materials Science (IMS) in Ho Chi Minh City) have been sold in limited quantities (several hundred units) most often at non-commercial prices for demonstration installations. Their efforts are to get the price of these better quality units down to US$45-50. The 'PowerPal' pico-hydro unit is an improved copy of the MTD series equipped with a basic voltage regulator and electronic load controller and improved bearing and generator arrangement with a local price of about US$85.

Generally pico-hydro systems are sold for cash in the open markets in Hanoi and other towns and cities, mainly in the northern provinces, by shops that deal with electrical equipment, pumps, generators, or agro-machinery. Although some very small subsidies have reportedly been available in certain provinces, for example from the national electricity distribution company, Electricité de Vietnam (EVN), the market is basically 'cash and carry' [W. Rijsenbeek, 2000]. In general the government of Vietnam is not providing funding for promoting pico-hydro and all the promotion has mostly been done by word of mouth [Nguyen Duc Loc, 2003].

2.2 Vietnam lessons learnt

Rural people install these systems in their own irrigation channels or even in public rivers or creeks. Usually concentrations are found where several families have built a small dam in the river to create a head difference and installed a number of systems. Wires to the houses (often without insulation) are supported by bamboo and cover distances up to 300m, although if the transmission line is as long as this the system performs poorly. The load is normally fixed, running a few lights continuously (to keep the generating voltage steady) and radio-cassette, black-white TV or electric desk-fan as required. There are often no sluice gates to stop water flowing to the machines nor any electronic controllers to govern their electrical output. When not in use, the units are simply removed from the small dams and left by the river-side or, more often taken home to prevent theft which has been a major problem.

The reputation of Vietnam in mass development of pico-hydro is at risk of becoming tarnished by various negative experiences, where approximately half of units originally installed are now out of service because of the uncontrolled supply of cheap, low-quality equipment from China. Surveys carried out in Vietnam [DFID, 2002-2004] showed that out of 29 farmers interviewed in the north-west, 55% had replaced their Chinese pico-hydro system at least once over a range of system lifetimes (1 to 12 years), with an average replacement of 1.8 times over 6 years. Coupled with the lack of useful information about the technology, this gives decision-makers a difficult task in selecting pico-hydro units over other more mature, similar sized renewable energy systems, such as PV or wind-chargers, even though pico-hydro costs are significantly lower.

However, despite the poor record of the pico-hydro market in Vietnam, higher quality equipment is available within the country and can still offer cheap and sustainable electrification to millions of low-income families in developing countries, especially those living in low-lying areas. The issues to be addressed to guarantee sustainability are being taken seriously by institutions in Vietnam and neighbouring countries such as the

Philippines where lessons are being learnt from the Vietnam experience. The pico-hydro market in Vietnam is still estimated to be in the region of 200,000 households and in the Philippines total market could be as large as 120,000 units over ten years [DFID, 2002-2004].

3. Economic analysis of pico-hydro

Pico-hydro technologies are part of a menu of options for bringing modern energy services to households in un-electrified areas of developing countries where the hydro resource exists. Analysis done in this ESMAP project of the comparative capital and operating costs for various renewable energy systems and small diesel/petrol gensets indicates that pico-hydro is one of the most affordable sources of electricity, with life-cycle costs for each household in the region of US$74 to US$150 a year compared to the life-cycle costs of solar, hybrid, wind or fossil fuel-based options which start at US$140 per household per year. If larger pico-hydro units are installed at the community level, the costs are shared between households and life-cycle costs for each household drop to about US$30-40 per year.

In considering whether pico-hydro technology is affordable to the poor, the project assumed that the ‘poor’ live on less than two dollars a day, or US$730 a year and that 6-9% of poor rural householders’ income is currently spent on forms of electrical energy [World Bank, 2001]. Then modern energy services must come at a price of US$44 to US$66 a year or less to be affordable to the poor. Given this basis, it can be seen that quality pico-hydro systems can only be affordable to the poor though community-based schemes where the costs are shared by a number of users.

However, if financing mechanisms can be encouraged for payments for pico-hydro equipment to be made over a number of years to dealers or service providers (with high quality pico-hydro units therefore requiring a life-span that exceeds this payback period), then the opportunities for the technology can be explored in new rural markets. Also it is seen that the rural poor will often try to exploit any reasonably affordable options for electricity open to them and the kilowatt-level pico-hydro technology can promote many end-uses (using AC power), generate income and employment, as well as being beneficial to women and children in terms of reduction of drudgery and better health, through encouraging electric cooking and brighter lighting.

4. Opportunities for pico-hydro in the Andean region

Analysis in Ecuador shows that the country has an exceptional hydropower potential and has had a fair amount of small-hydro developments in the past, but that the majority of the smaller hydropower projects have fallen into disuse. Despite having over three-quarters of its rural areas electrified, there is seen to be a large market opportunity for pico-hydro in the country.

A methodology for estimation of the genuine pico-hydro market in Ecuador and the four other nations of the Andean Region (Peru, Bolivia, Columbia and Venezuela) was developed by looking at rural electrification rates, different morphological areas in each country defined accordingly to rainfall, topography and how rivers are spread across the region and local capacity and willingness to pay factors. This analysis has shown that there is an near-term pico-hydro market of a minimum of 16,000 households in Ecuador, out of a technically achievable total of 137,000 un-electrified residences that are off grid and near to the required hydraulic resources. The neighbouring Andean countries show even more potential, especially Peru and Bolivia with a minimum of 98,000 and 55,000 households (see Table 1). The total of 180,000 to 360,000 genuine household market estimated in this project could contribute between 7% and 15% of the households yet to be electrified in these countries.

Country	Non-electrified rural households	Technical achievable no. of households that could use pico-hydro	Range of genuine household market based on capacity and willingness to pay
Bolivia	515,815	355,000	55,000 – 109,000
Peru	1,462,783	671,000	98,000 – 197,000
Ecuador	249,199	137,000	16,000 – 32,000
Colombia	127,343	39,000	7,000 – 14,000
Venezuela	72,170	28,000	4,500 – 9,000
Total	**2,427,310**	**1,230,000**	**180,500 – 361,000**

Table 1 - Market size for pico-hydro in the Andean Region

An assessment of the market demand for pico-hydro systems globally has also been carried out for the main countries thought to be appropriate for such development [DFID, 2002-2004]. The genuine household market potential for low-head pico-hydro in the five Andean countries compares to a global potential calculated of about 4 million units and 740,000 estimated for all of Latin America (Brazil has the highest potential due to its relative higher population).

The experience learnt in the pico-hydro sector from Asia, where hundreds of thousands of systems have been sold in the last 15 years on a cash-and-carry basis, has shown that it is also realistic to deploy this many pico-hydro units in Ecuador and the Andean region. Recent developments in the Philippines and through this project in Ecuador have shown that there is a model for the sustainable deployment of pico-hydro, but that this requires higher quality equipment and engineering support.

5. Ecuadorian pico-hydro pilot projects

Part of the ESMAP project was the demonstration of pico-hydro technology through the establishment of 31 pilot projects in Ecuador. The choice of regions was made through a resource and needs assessment by consulting with Dirección de Energías Renovables y Efficiencia Energética (DEREE)[1] in the Ministerio de Energia y Minas (MEM)[2]. Figure3 and 4 give impressions of the two types of pico-hydro systems (low- and medium-head) installed in the five communities of Chimboazo province in the Andes and Napo province in the Amazonian basin.

Figure 4– Vietnamese 200 W low-head pico-hydro 'propeller' unit installed in Ecuador

Figure 5 – Vietnamese 200 W medium-head pico-hydro 'turgo' unit installed in Ecuador

After the pico-hydro units had been installed, 'End-User Manuals' were disseminated and on commissioning of the projects, the end-users signed a 'Terms of Reference' that showed the responsibilities of the various parties involved in the project including the dealers that were trained to install the pico-hydro units. After the 12 months warranty offered under the project, a transfer of the pico-hydro systems was made to the end-users because they had given their time and labour for setting up the pilots and had purchased the appropriate wiring, bulbs, switches and electrical sockets in their houses as well as taking on the long-term maintenance of the civil works and equipment.

5.1 Pico-hydro pilots costs

The cost analysis of the installation work has been divided into six categories and estimates have been made on the operation and maintenance (O&M) costs for the pilots, which will help potential investors to analyse the feasibility of developing the market and how to tackle the different links of the commercialisation chain.

1. Costs at origin - US$145 for each pico-hydro unit from Vietnam.
2. Importation and nationalisation costs – US$51.27 pro-rated for each of the turbines (this was for a small batch and costs would drop for importing a larger number).

[1] Department for Renewable Energy and Energy Efficiency
[2] Ministry of Energy and Mines

3. Costs of parts built locally - flumes for the low-head turbines only were made locally for US$70 each.
4. Civil works – the costs of this varied but included cement, pipes and bags of sand with the average cost per unit US$67.79. The labour was provided by the community itself under the supervision of the project team and the local dealers.
5. Electric distribution costs – these were the highest infrastructure costs due to the high price of cables in Ecuador and in all cases “duplex insulated wires” were used for safety. The cost of wooden poles was also included but the labour for digging and raising the posts was provided by the community. The average cost per unit was US$107.81 with higher cost in the Andes village due to longer transmission lengths.
6. Installation costs - local dealers were paid to supervise the progress of the installations at site at proper market rates to reflect the real value that they would charge for future installations. Costs per unit averaged at US$50.50.

With completion of the 31 pilot demonstrations (the whole process of ordering to installation took 7 months), the costs associated with deployment totalled an average of **US$475 per unit**. The operational and maintenance costs are estimated to be **US$5 per year** (for greasing and changing bearings) and given a conservative equipment life of only 5 years (although it is thought that the quality equipment used could reasonably last 15 years), an end-user would need to save **US$40 per year** to purchase another pico-hydro system worth US$200.

Given these costs, the opportunities for further expansion of the market for good quality pico-hydro products within Ecuador clearly now exists in certain segments, and this should also be used to guide both the neighbouring Andean Region countries and other parts of Latin America.

6. Building a sustainable local commercial infrastructure

Having successfully demonstrated pico-hydro technology in association with local dealers in Ecuador, the project also sought to build the foundation for a sustainable local commercial infrastructure for the technology, through two levels of action: firstly, a training course for installation and maintenance aimed at engineers and technicians; and secondly, business discussions about pico-hydro business opportunities with potential importers and companies that have the rural infrastructure in place that would enable them to eventually act as dealers.

The main result of these activities was the confirmation that many people and companies are interested in acquiring these units and they recognise that a potential market exists in the country. In the Amazon region especially, there is strong pico-hydro market for rural isolated households with cattle estates. The low-head technology can be a solution there for much of the current demand for modern electricity services as it can fit the need for productive uses, such as dairies and small-scale milling.

There are interested companies that have sufficiently strong financial capacity to be able to stock units at their sale points distributed throughout the country. It is recognised that it is important to have units physically exhibited and even better in operation, in order to generate sales interest. However, some potential dealers do not believe that pico-hydro units offer a solution that would be of interest within their market as the systems have a very low power capacity and may not be very profitable for them. They believe the best choice for isolated communities with hydraulic resources is micro- or mini-hydro connected to an isolated grid.

There is also a requirement from some potential dealers for technical support services and clarity about the commercial and financial conditions for importation and delivery channels before risking a new business. They believe that much more evaluation of the market as a whole in Ecuador would have to be done along with training and information dissemination about pico-hydro to potential beneficiaries in the rural areas, highlighting the impact the technology could have on livelihoods through power for productive uses.

7. Local impact

The impact of the pilots on end-user beneficiaries has been carefully considered in the project. The benefits include an increase in the quality of life, with the better lighting systems enabling community activities during the evenings. The beneficiaries have pointed out that fuel savings were made and there was an increase in the productive output as well as increased opportunities for educational and social activities.

Through the Rapid Rural Appraisal (RRA) undertaken and the training of users, along with the actual implementation of the pilots, the end-users overcame their initial apprehension about the technology and now have confidence in maintaining the pico-hydro systems and have also acquired additional skills. It is clear that for reliable and long-lasting installation, operation and maintenance of pico-hydro systems, proper site assessment, training of both owner and operator, as well as provision of safety and best practice guidelines are essential.

It has also been found that the demonstration of pico-hydro technology has created a market development effect where requests for more systems have been made within the target villages and by neighbouring communities. The private sector, government and international donors can all play a part in supporting the scale-up of pico-hydro deployment in Ecuador, providing an example to other Andean countries, and other developing countries alike.

Conclusions and Recommendations

Pico-hydro (sometimes called 'family-hydro') is a comparatively cheap electrification option suitable for a single household or a small group of households and there are a few countries that have large numbers of pico-hydro systems installed in rural areas, most notably Vietnam, Nepal, Lao PDR and South West China. These are also extremely poor regions of Asia with annual household incomes as low as US$300-400 per year. Yet there have been over 120,000 pico-hydro units installed in the last 10-15 years in the Vietnam alone, and over a thousand Peltric sets installed in Nepal.

The majority of these systems have been paid for poor farmers without any subsidy intervention. The price of the most popular (Chinese) pico-hydro units is as low as US$20 (excluding the cost of installation). This cash-and-carry model may have worked for huge numbers of rural poor, but the reality is that less than half of the low-head pico-hydro systems purchased is still in operation, due to the low quality and short-life of equipment, and there have been serious safety issues occurring.

Through this ESMAP project, it has been shown that pico-hydro can provide services to low income families in rural areas in Ecuador. There is a segment of the rural population for which pico-hydro is certainly affordable, but much more awareness is required of the potential benefits of the technology over other forms of off-grid electrification (e.g. diesel gensets). However, financing support may still be required to enable the poorest customers to be able to afford a pico-hydro system, particularly if good quality technology is to be used and installed in a proper manner.

It is clear from the experience gained in this project that a 'dealer' energy service model, with post-sales maintenance support that is fed by currently available good quality equipment, would provide a more useful product to rural people in general and to the 'poor' rural population that can only buy pico-hydro units over a period of time.

There do remain some obstacles before potential dealers will entertain pico-hydro commercially in Ecuador, but overcoming these is achievable. For example, a more thorough understanding of the latest technology through input from manufacturers and suppliers from Asia will give local dealers confidence and it will be important for the conditions surrounding the importation of large numbers of pico-hydro units to be clarified.

Many more potential dealers would come forward if a proper evaluation was done of the actual market locations and how pico-hydro can add value to products and give possibilities for productive uses in these locations. At the same time, in order to motivate participation in projects this study should be complemented with training and information dissemination about pico-hydro to potential beneficiaries.

In addition to these aspects being in place, in order to make this model commercially viable and to scale-up the use of pico-hydro in developing countries, what is now required is concentration upon establishing standards and certification/licensing for the products; provision of technical support for feasibility studies, site level installation, operation, and maintenance and warranty; and close community liaison is crucial in determining how pico-hydro technology is best organised at the end-user level. For example, beneficiaries may need to provide their labour and local materials to reduce initial capital costs, pay for and carry out proper operation and maintenance and understand the importance of using the technology within its capability.

Subsidy for the capital costs of pico-hydro technology is not a priority area except perhaps for the poorest of the poor whereby some of the capital costs for quality systems (US$ 475 per 200 W unit in this project) are assisted by national renewable energy programmes while households meet the O&M costs and savings for the next new turbine of US$45 per year.

Support is required, however, for quality assurance/licensing of the equipment from national energy ministries together with universities that have appropriate testing facilities; support to stimulate the establishment of easier importation of technology and new sales infrastructure through regional bodies and the appropriate government departments; and provision of seed money to help institutions to set up engineering support services from multi- and bi-lateral agencies. This can also be done in conjunction with the private sector (dealers, rural energy service companies (RESCOs) rural banks, entrepreneurs etc.) as well as non-government organisations (NGOs).

By taking action to ensure that good quality equipment is promoted and installed properly, pico-hydro will be able to provide hundreds of thousands of households living in rural areas of developing countries with a reliable and relatively cheap form of electricity that can help to improve their standards of living and quality of life.

References

1. **Glenn Whalan**, Asian Phoenix, personal discussion, 2003.
2. **ASTAE, World Bank,** "Options for Renewable Energy in Vietnam", 2000.
3. **RERC (Rural Energy Research Center),** Hanoi, "Pico-hydro Market and Costing in Vietnam", 2003.
4. **Institute of Energy in Vietnam**, Hydropower Department statistics, 1996.
5. **W. Rijsenbeek**, ISES RESuM Project, 2000.
6. **Nguyen Duc Loc**, RERC, interview, 2003.
7. **DFID** KaR Project R8150, 'CDM pilot project to stimulate the market for family-hydro for low-income households' - 2002-2004.
8. **World Bank**- Survey of unenergized households in Philippines, 2001.

The Authors

Simon D.B. Taylor is a senior engineer in the Hydro Group of IT Power and a specialist in rural energy issues and micro- and pico-hydro power. In 2004 he spent a year in China working on village power systems and liaising with the Chinese small hydropower industry. He has been involved in mini-hydro feasibility studies in Honduras, Nicaragua and the Philippines by visiting potential sites and interviewing community leaders and hydro developers and has helped establish 30 pico-hydro projects in Ecuador which included training of community and private sector stakeholders in the technology. Prior to IT Power he worked in the Philippines on micro-hydro and solar projects and gained experience in rural development and climate change issues.

Dr. Manuel Fuentes is a senior engineer and Latin America specialist at IT Power and has 10 years of experience in the engineering of renewable energy and hybrid systems and in the evaluation of renewable energy resources. He has a broad range of experience in assisting in the development of renewable energy, feasibility studies, resource assessments, economics, policy, design and project management of energy projects. He has worked as a consultant for the World Bank, the European Commission, UNDP, UK Department of Trade & Industry, and numerous private clients in Argentina, Cuba, Nicaragua and Ecuador. He also acts as a visiting lecturer at Oxford Brookes University and Universidad de Buenos Aires.

Dr. John Green is the Manager of the Climate Change Group at IT Power, has worked in the renewable energy field for 15 years, having completed his PhD focusing on renewable energy in developing countries. He has managed a wide range of projects funded by UN organisations, the EC and the World Bank, and is author to several publications on renewable energy and energy policy. He has worked on many Clean Development Mechanism projects, including designing a US$ 1.3 million CDM capacity building programme for industry in China, developing a baseline study for a 25.8MW windfarm in Inner Mongolia, and working on projects investigating the opportunities for bundling small-scale projects under the CDM. He is presently working on several energy policy projects focusing on Green Electricity, Tradable Renewable Energy Certificates, Guarantees of Origin and Electricity Disclosure.

Dr. Kavita Rai has extensive experience in the field of renewable energy and water resources in developing countries. Her expertise lies in the planning, designing and implementation of socio-economic studies and projects particularly in small-scale hydropower schemes. She is also experienced in gender and poverty assessments. She has performed consultancies in renewable energy as well as other development related projects both in Nepal, where she worked for 8 years and internationally. Prior to joining IT Power, she was based at the Center of Development Research in Bonn, Germany for 3 years completing a PhD degree specializing in the social aspects of dam development.