Jean-Claude Bolay · Silvia Hostettler
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Technologies for Sustainable Development

A Way to Reduce Poverty?

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United Nations Educational, Scientific and Cultural Organization

UNESCO Chair in technologies for development Lausanne (Switzerland)

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Foreword

Science and technology are accepted as the driving forces of economic growth and social progress. Since the end of the twentieth century, they also constitute the most promising instruments to fight against two afflictions undermining the stability of our planet: the deterioration of environmental resources and the ensuing climate change; and the reduction of poverty, which today still affects close to 20 % of the world population.

World Bank statistics show that more than 1.4 billion individuals live on less than US$ 1.25 per day. This reality concerns all of us, and every one of us is moved, wherever we may be, with our knowledge, our expertise, and our desire to improve the living conditions on our planet, for the benefit of all.

Scientists, researchers, and teachers are not oblivious to this mobilization. For too long, they have been accused of living in an ivory tower. However, this does not take into account that numerous scientific inventions, technological innovations, and studies have allowed the implementation of products that promote sustainable development, and that have a positive impact, environmentally, as well as in social and economic terms—whether taking into consideration, for example, solar energy, already widely spread across the world and steadily improving, or telecommunications, that have led some authors to say that we now live in a "global village".

If such a conference has been convened at the Ecole Polytechnique Fédérale de Lausanne (EPFL), it is because we are collectively aware that the stakes in development are tremendous at the global level; inequalities persist and even tend to expand in certain regions of the world. As scientists and instructors of future engineers, we work at the earliest stages of achievements, which, one day, will change the lives of the World's citizens, but we also know that sometimes it will be many years before laboratory discoveries are applied in the field. It is therefore quite natural that we aim to strengthen relationships between researchers and decision-makers; between scientists and industrialists; between academics and beneficiaries; because it is from this dialogue that the best adapted solutions to social demands and recognized needs shall emerge. This dedication to excellence in education and research, to the internationalization of our collaborations and our projects, and to solidarity have long guided EPFL.

The 2012 EPFL UNESCO Chair International Conference on Technologies for Development reminds us that "planning and acting together" is a global objective. This concern will be pivotal to our discussions. Three key questions will steer the work of the conference:

- What is an appropriate technology? In aiming to better determine the real needs of the people in developing countries and in which way technology can address these needs;
- How to ensure an integrated sustainable development? In promoting interdisciplinary research and establishing partnerships that bring together various actors in development, public authorities, civil society, industry, and international organizations;
- What are the conditions for the co-creation and transfer of such technologies? By ensuring through appropriate methods and the exchange of knowledge, the sustainability of the innovations in the field and that their impact is beneficial to all.

Prof. Philippe Gillet
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The UNESCO Chair in Technologies for Development at the Ecole Polytechnique Fédérale de Lausanne (EPFL) is grateful for the time and effort of the many contributors leading up to this publication. In particular, we would like to express our appreciation to Prof. Philippe Gillet, Vice-President for Academic Affairs at EPFL, for his unfailing support to the Cooperation & Development Center (CODEV) and his inspiring participation at the UNESCO Conference on Technologies for Development 2012 at EPFL.

Through openly sharing their considerable expertise and different outlooks, the keynote speakers at the UNESCO Conference contributed significantly to its success. Our heartfelt thanks go to Dr. Lidia Brito, Dr. Martin Dahinden, Dr. h.c. Pierre Landolt, Prof. Miguel Nicolelis, and Prof. Luc Soete for their highly appreciated involvement and support.

Likewise, this project could not have succeeded without the quality and diversity of the contributions of the various authors and researchers. In response to the call for papers, a Scientific Committee composed of experts from academic and non-academic institutions evaluated over 145 papers and ultimately selected 82 to be presented at the Conference. Of these, 20 were finally chosen for the originality of their approach to the publication's theme, "Technologies for Sustainable Development". We express our gratitude to all these authors, without whom this publication would not have been possible.

Our sincere thanks are extended to all our colleagues in CODEV at EPFL for their ideas, commitment, and for their encouragement.

We are very grateful for the generous patronage of the Swiss Agency for Development and Cooperation (SDC), the Canton de Vaud, the City of Lausanne, Landolt & Cie, Swiss Private Bankers, Cleantech Alps and the Commune of Saint-Sulpice, the conference sponsors. Their support and their partnership is critical to the achievement of our common mission which is to identify innovative solutions that are able to reduce poverty and lead the way toward more sustainable development at a global level.

Contents

Acronyms

ABPMDD	Agribusiness Promotion and Marketing Development Directorate
ACPP	Academic Cooperation Palestine Project
ACRA	Cooperazione Rurale in Africa and America Latina
AD	Anaerobic Digestion
ADB	Asian Development Bank
AEDE	Agence pour l'Energie Domestique et l'Environnement
AEPC	Alternative Energy Promotion Center
AFD	Agence Française de Développement
AG	Above Ground
ALNAP	Active Learning Network for Accountability and Performance in Humanitarian Action
ARIJ	Applied Research Institute Jerusalem
AT	Approriate Technology
ATT	Average Effect of Treatment on Treated
BCAS	Bangladesh Centre for Advanced Studies
BEE	Bureau of Energy Efficiency
BEEP	Building Energy Efficiency Programme
BHWDB	Bangladesh Haor and Wetland Development Board
BMU	Barrier Monitoring Unit
BoP	Bottom of the Pyramid
BSP-N	Biogas Sector Partnership Nepal
CBO	Community-Based Organizations
CBS	Central Bureau of Statistics
CCD Commission	Commission on Climate Change and Development
CCD	Climate Change and Development Division
CCT	Controlled Cooking Tests
CDE	Center for Development and Environment, University of Bern
CDMP	Comprehensive Disaster Management Programme of Bangladesh

CEA	Central Electricity Authority
CEAT	Communauté d'études pour l'aménagement du territoire (Urban and Regional Planning community)
CEGIS	Center for Environmental and Geographic Information Services
CFA	Central African CFA Franc
CFL	Compact Fluorescent Light
CFU	Colony Forming Unit
CH_4	Methane
CHF	Cooperative Housing Foundation
CIAD	Centre for Integrated Agricultural Development
CIDA	Canadian International Development Agency
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CODEV	Cooperation & Development Center
CPC	Compound Parabolic Collector
CRED	Centre for Research on the Epidemiology of Disasters
CRiSTAL	Community-Based Risk Screening Tool, Adaptation, and Livelihood
CTA	Centre des Technologies Appropriées de Maroua
DBPs	Disinfection By-products
DNA	Deoxyribonucleic Acid
DOM	Dissolved Organic Matter
DRR	Disaster Risk Reduction
DTI	Department of Trade and Industry
DTU	Development Technology Unit
E. coli	Escherichia coli
ECBC	Energy Conservation Building Code
EPFL	Ecole Polytechnique Fédérale de Lausanne
FAO	Food and Agriculture Organization of the United Nations
FAP	Flood Action Plan
GDP	Gross Domestic Product
GO	Governmental Organization
GO- > SPIN	Global Observatory of Science, Technology, and Innovation Policy Instruments
GPCC	Global Program for Climate Change
GTZ	German Agency for Technical Cooperation
H_2S	Hydrogen Sulfide
HA	Hectare
HDRO	Human Development Report Office
HFA	Hyogo Framework for Action
HP	Horse Power

HRT	Hydraulic Retention Time
HVAC	Heating Ventilation and Air Conditioning
hν	Light Irradiation
IAP	Indoor Air Pollution
ICIMOD	International Center for Integrated Mountain Development
ICOM	Steel Structures Laboratory
ICRC	International Committee of the Red Cross
ICS	Improved Cook Stove
ICSU	International Council for Science
ICT	Information and Communication Technology
IDE	International Development Enterprise
IEA	International Energy Agency
IETC	International Environmental Technology Centre
IFRC	International Federation of Red Cross and Red Crescent Societies
IGA	Income Generating Activities
IIED	International Institute for Environment and Development
iisd	International Institute for Sustainable Development
IMCI	Integrated Management of Childhood Illnesses
IOE	Institute of Engineering
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IR	Islamic Relief
IRMA	Institute of Rural Management Anand
IRRI	International Rice Research Institute
ISRO	Indian Space Research Organization
IUCN	International Union for Conservation of Nature
KBM	Kernel-Based Matching
KFPE	Swiss Commission for Research Partnerships with Developing Countries
KIST	Kigali Institute of Science and Technology
KPT	Kitchen Performance Test
KSPB	Kerala State Planning Board
kW	kiloWatt
L	liter
LASIG	Research Laboratory for Geographic Information Systems
LCA	Life Cycle Assessment
LDC	Least Developed Countries
LEAF	Livelihoods, Empowerment, and Agroforestry
LED	Light Emitting Diodes
LFC	Large Fog Collector
LMCT	Ligand to Metal Charge Transfer
LPG	Liquefied Petroleum Gas

LPL	Lower Poverty Line
LULC	Land-Use/Land Cover
MACE	Malawi Agricultural Commodity Exchange
MAG	Mine Action Group
MDD	Marketing Development Division
MDG	Millennium Development Goals
MF	Membrane Filtration
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
Milli-Q water	Ultrapure water
MIS	Market Information Services
MK	Malawi Kwacha
MMM	Mahalanobis Metric Matching
MOF	Ministry of Finance
MOFDM	Ministry of Food and Disaster Management
MoP	Ministry of Planning
MPWH	Ministry of Public Works and Housing
NARC	Food Research Division, National Agriculture Research
NBKM	Cultural Network of New Belgrade" Association
NBTDP	North Bengal Terai Development Project
NCATSU	North Carolina Agricultural and Technical State University
NEA	Nepal Electricity Authority
NGO	Non-Governmental Organization
NH_4–N	Ammonium–Nitrogen
NIE	New Institutional Economics
NNM	Nearest Neighbor Matching
NOM	Natural Organic Matter
NP	Nepal
NPC	Nepal Planning Commission
NRC	National Research Council
NRC	Norwegian Refugee Council
NSERC	Natural Sciences and Engineering Research
O&M	Operation & Maintenance
OCHA-oPt	United Nations Office for the Coordination of Humanitarian Affairs in the occupied Palestinian territory
OECD	Organisation for Economic Co-operation and Development
OH	Hydroxyl Radicals
oPt	Occupied Palestinian territory
P	Phosphorus
PAPP	Programme of Assistance to the Palestinian People
PBF	Performance-Based Financing
PCA	Plate Count Agar
PCBS	Palestinian Central Bureau of Statistics

PCIA	Partnership for Clean Indoor Air
PET	Polyethylene Terephthalate
PH	Philippines
PLW	Physiological Loss in Weight
PNA	Palestinian National Authority
PPPP	Public Private People Participation
PVS	Participatory Variety Selection
Quv,n	Accumulated Energy
R&D	Research and Development
RCS	Rural Cold Storage
REC	Electronic Consultation Register (Registre Electronique de Consultation)
RM	Radius Matching
RMB	Renminbi, official currency of China
ROS	Reactive Oxygen Species
RW	Rwanda
S&T	Science & Technology
SDC	Swiss Agency for Development and Cooperation
SEI	Stockholm Environment Institute
SIDA	Swedish International Development Cooperation Agency
SIDS	Small Islands Developing States
SJTU	Shanghai Jiao Tong University
SL	Sustainable Livelihoods
SME	Small and Medium Enterprises
SNSF	Swiss National Science Foundation
SODIS	Solar Disinfection (Batch-process Solar Water Disinfection)
SRT	Solid Retention Time
SSA	Sub-Saharan Africa
SSF	Slow Sand Filtration
STI	Science Technology and Innovation
STIGAP	Science Technology and Innovation Global Assessment Programme
STS	Science and Technology Studies
TCE	Transaction Cost Economics
Tdh	Terre des hommes
THMs	Trihalomethanes
TS/TSS	Total Solids/Total Suspended Solids
UDMC	Union Disaster Management Committee
UG	Underground
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme

UNEP	United Nations Environment Programme
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNISDR	United Nations International Strategy for Disaster Reduction
UNITWIN	University Twinning and Networking Programme
UNRWA	United Nations Relief and Works Agency for Palestine Refugees in the Near East
UP	Union Parishad
US DOD	United States Department of Defense
USAID	US Agency for International Development
USSR	Union of Soviet Socialist Republics
UV-A	Ultraviolet A
UV-B	Ultraviolet B
UV-C	Ultraviolet C
UXO	Unexploded Ordnance
VARG	Vulnerability and Adaptation Resource Group
VITA	Volunteers in Technical Assistance
VRC A	VRC Attendees (Coffee Planters)
VRC NA	VRC Non-Attendees (Coffee Planters)
VRC NANV	VRC Non-Attendees (Coffee Planters) from Neighbouring Villages
VRC	Village Resource Centre
VS	Volatile Solids
VSAT	Very Small Aperture Terminal
W	Watt
WASH	Water, Sanitation and Hygiene
WB	West Bank
WB	World Bank
WBT	Water Boiling Test
WHO	World Health Organization
WOCAT	World Overview of Conservation Approaches and Technologies
XAF	Central African CFA Franc

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Part I
Introduction

Chapter 1
Technologies and Partnerships

Silvia Hostettler and Jean-Claude Bolay

Abstract Appropriate technologies are technologies that are socially, culturally, environmentally and economically accepted by the stakeholders. It is necessary, therefore, to develop appropriate technologies in partnership with researchers, government agencies, and industry. It is essential that this be done in a process of co-creation with the beneficiaries. The development of appropriate technologies must also include the appropriate strategy to implement and maintain them. Innovative technologies have a central role to play in the effort to alleviate poverty in this world, which today is still overwhelming, with 20 % of the world population living on less than US$1.25 per day. The development of technologies that are adapted to unreliable energy systems, or the lack of transportation or communication infrastructure is indeed challenging. There are important constraints and requirements that need to be addressed for any technological development to succeed. However, it is encouraging to see that the development potential of appropriate technologies is much larger than the challenges, as shown in this publication's case studies from fields as diverse as agriculture, renewable energy, disaster risk reduction, ICTs and human settlements.

1.1 Introduction

One of the recurrent questions related to technologies for development is: "Are the technologies appropriate for the promoters? – Or for the users?" This debate needs to be placed in the current context that is structuring the contemporary world and can no longer merely be reduced to a simple North–South opposition. During the last 30 years, new economic powers have emerged, enjoying the benefits of

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globalization (liberalization of trade barriers and acceleration of communication technologies, among others) (England and Ward 2008), while having to face enormous challenges associated with climate change, urbanization, and poverty that economic growth has only partially managed to curb (Stiglitz 2007). Even though the number of the poor has globally decreased in percentage, social inequalities have increased. Moreover, it is the rural and urban poor who remain at the margin of progress, whether in social, health related or technological advancement. In thinking of their practical applications, technologies must be adapted to climatic, cultural and economic contexts (Bolay 2004), allowing beneficiaries – professionals, clients, and citizens – to master them, and therefore ensure optimal and sustainable utilization. If sustainable development aims to take fuller account of environmental factors, and implement technologies to reduce negative effects in this field, it also has to promote a more inclusive society and an economy that is not only focused on short-term profit.

However, many companies from the West, as well as from emerging countries, are looking for new markets while attempting simple technology transfers that will not be successful as long as the technology is not adapted to its users and local environment. For instance, according to the World Health Organization (WHO) "about 70 % of the more complex [medical] devices do not function when they reach their destination in developing countries". Among the main causes identified is the instability of the equipment to resist sudden changes in electrical current, because it succumbs to heat, dust or moisture, or simply because there is no one who knows how to use or maintain it (WHO 2010). Clearly, this type of technology is not adapted to the needs of many developing countries. As this is being recognized, a number of research teams, among them *EssentialTech*[1] at the Ecole Polytechnique Fédérale de Lausanne (EPFL), are developing medical equipment that inexpensive, robust, easy to use, and most importantly; developed in partnership with the beneficiaries and industry. Being affordable is already a step in the right direction; however, it does not mean technologies will be adopted if they do not respond to the needs of the beneficiaries. Chapter 7 on appropriate irrigation technologies in India, for instance, shows that low-cost is not always the determining factor in whether a farmer is willing to invest or not in a certain technology. Farmers preferred to pay for renting motorized irrigation pumps instead of opting for low-cost but labor-intensive traditional treadle pumps, as advocated by most non-governmental organizations (NGOs).

An appropriate technology has been defined as socially, culturally, environmentally and economically accepted by the stakeholders (Pearce et al. 2012; IETC 2003). For a technology to satisfy as many of these criteria as possible, it has o be developed in partnership with all stakeholders namely researchers, industry and civil society. The *EssentialTech* program goes even further by developing an entire value chain from the technical design to the deployment business model, including manufacturing, logistics, commissioning, usage, maintenance, waste and

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[1] http://essentialtech.epfl.ch

recycling. This requires an interdisciplinary approach and partnerships with global and local players in the private sector and with public authorities and civil society. However, it is inevitable that a compromise will have to be made between the adaptation of a technology to a specific local context and the objective of large-scale deployment. This represents an important challenge because the perspective of a large-scale industrial production requires standard designs to keep costs down, while some level of adaptability to local specificities still needs to be maintained. Local capacity building is a key factor for successful deployment of technology, not only regarding the correct use of the technology and the maintenance, but also with regard to having the ability to identify the local needs of different groups of stakeholders that may have conflicting preferences. Furthermore, capacity building is often required to enable local stakeholders to develop a long-term vision based on sustainable development and the necessary commitment to pursue it. Therefore, it is imperative that the development of appropriate technologies also includes the appropriate strategy to implement and maintain them. Such an approach is essential to reach the ultimate objective of technologies for development, namely the reduction of poverty, which today is still overwhelming, with 20 % of the world population living on less than US$1.25 per day (World Bank 2011).

In this publication, the concept of partnership is discussed extensively. Successful partnerships are based on trust and communication and ultimately on a willingness to share power amongst stakeholders. The ideal manner in which to realize this has been analyzed in-depth by the Swiss Commission for Research Partnerships with Developing Countries (KFPE).[2] Guidelines were elaborated and formulated in 11 principles based on the belief that a fruitful partnership is "*a continuous process of sound knowledge generation, building mutual trust, mutual learning and shared ownership*" (KFPE 2012). Building a successful partnership begins by setting the agenda jointly, is carried forward by being accountable to beneficiaries and is completed by securing the outcomes. These are just three of the 11 principles on which partnerships should be built. Few partnerships will manage to implement all 11 principles faultlessly; however, all partnerships should make a serious attempt to do so. Interestingly, KFPE has also examined seven key questions regarding research partnerships, starting with the most obvious one: Why work in partnership? First, it can broaden perspectives and networks, provide institutional access and enrich the research process, many authors in this publication argue, however, that – more importantly – technologies in developing and emerging countries will most likely fail if they are not developed in partnership with stakeholders from the local context. For instance, as described in Chap. 6, the partnership between the International Committee of the Red Cross (ICRC) with local organizations, and in particular the clarification of the stakeholder's responsibility – another of the 11 KFPE principles – was crucial for the successful implementation of biogas sanitation systems in prisons in Nepal, Rwanda and the Philippines. After one year of operation, 11 of the 13 implemented systems

[2] http://www.kfpe.ch

were still functioning with excellent results in terms of technical performance, economic viability, environmental impacts and social acceptance. Other organizations, such as *access2innovations* based in Denmark, specialize in bringing together and administering networks to form partnerships around specific technological innovations for development. In Chap 13 David Christensen presents a case study from Vietnam in which a commercial venture was founded to address waste management issues based on innovative technology. This project was implemented in partnership with CARE International in Vietnam and Denmark, Danish companies and local authorities in Vietnam. These examples show that inter-cultural partnerships will inevitably lead to exchanges on underlying values, which effectively promote relevant research contributions in a development context. The systematic involvement of local communities and authorities accompanied by capacity building and knowledge sharing significantly multiply the chances of successful project implementation and ensuring long-term benefits. One of the main challenges remains the sharing of power and knowledge amongst the actors. This is crucial and at the same time quite difficult to achieve as, for instance, the management of intellectual property rights still poses major obstacles to equitable sharing of costs and benefits.

In an attempt to describe a process of technology development that is being done in partnership with the relevant stakeholders, the notion of co-creation is increasingly being used. Co-creation is considered to be more successful than technology transfer due to the fact that local users are involved from the conception, thereby steering the technology development in the direction most aimed at beneficiaries' needs and the local context. Interestingly, information and communication technology (ICT) itself is empowering a growing number of intended beneficiaries in developing countries to increasingly influence the development initiatives that are planned for them (Pearce et al. 2012; Thompson 2008).

Several papers in this publication illustrate the benefits of involving the beneficiaries throughout the process of technology development. For instance, in Chap 3, focusing on improving housing for the poor, Sytse de Maat argues that by involving the slum dwellers, better-adapted solutions can be identified instead of using industrially produced dwellings.

Industrially produced dwellings are typically used in slum rehabilitation programs with varying degrees of success. Sometimes the new type of dwelling drastically changes the lifestyle of the intended beneficiaries. There are cases where informal settlements are replaced by standardized mass housing with little participation by the inhabitants of the slums. The author maintains that an appropriate strategy consists in changing from a "user-participation" to a "user-driven" development thereby using the creativity of the users for developing the appropriate technology that does indeed respond to their needs. After all, they have managed to create informal settlements for themselves for decades. Chapter 14 by Marija Cvetinović also illustrates the potential of ICTs to empower civil society in Serbia. ICTs allow them to become actors in the transformation and creation of their cities via a virtual resource database. So, what can be done to support processes of co-creation? Which methods and instruments can be used? Chapter 11 by

Francesco Vitali on the development of improved cooking stoves in the Logone valley in Chad and Cameroon illustrates an approach that is based on the involvement of the beneficiaries at each step of the project. The aim of the project was to reduce wood consumption by improving the cooking technology and generating income. Initially, local cooking practices were examined and discussed with the local community in order to be able to meet their needs and priorities. Then, the technical performances of several stoves were tested; and finally, the *Centreafrican stove*, a model suggested by the local research center, was chosen, thereby ensuring long-term production systems and maintenance. This study also serves as a good example to illustrate how local knowledge can be included in research that is otherwise rarely well undertaken. Another excellent example is the work of Mahesh Neupane on developing rural cold storage systems in Nepal in Chap 9. In many rural areas of Nepal, electricity is unreliable or absent, therefore electricity-based storage systems like refrigerators for fresh farm produce are not an option. Mahesh developed a rural cold storage system (RCS), based on evaporative cooling and constructed with local materials such as bricks, sand, water, clay, straw, and bamboo, in close collaboration with the local farmers. The RCS can be constructed at a total cost of maximum US$120-$130 for a storage capacity of 200–300 kg of farm produce.

The concept of co-creation is used to describe a process where innovation is based on cooperation and mutual learning and takes into account not only the technological aspects but also the broader organizational, economic and social context. While the benefits of early involvement of local partner institutions and beneficiaries remains undisputed, there may be cases where an introduction of disruptive technologies meets with resistance from local population and politics; but this can potentially raise awareness about environmental issues and support policy changes. Chapter 23 on the introduction of fog collection technology developed by a Canadian NGO in Chile and Guatemala shows how a project that started with a technology transfer can evolve into a co-creation participatory process substantially increasing local organizational capacities.

New technologies can improve the lives of many people, but they can also worsen the situation for those not having access to them, or even create conflict regarding access and benefit sharing (Ferguson et al. 2010). For instance, if a minimal financial contribution by the beneficiaries is needed to access a technology, this might be impossible for those who are extremely poor. Therefore a new technology can potentially increase the divide between the poor and the very poor. Consequently, successful technology development and deployment is not enough. Thorough knowledge of the local context is also required to put measures into place that allow the adoption of the technology by all segments of the intended beneficiary population. This might involve providing training to those who do not know how to use or benefit from the technology.

In Chap 20 on research and innovation, Luc Soete highlights the importance of endogenous innovation processes that are replacing the traditional technology transfer or imitation models. In the new models, he argues that re-using and recombining existing technologies with new knowledge will very often result in the most appropriate technology because it has been developed by local users in local contexts where the technology will actually be used. Therefore he argues, the notion of "appropriate innovation" reflects this process better than "appropriate technology". Soete goes further by arguing that reverse transfer of technology – feedback from the Bottom of the Pyramid[3] (BoP) users in the South to designers and technology developers in the North – might arguably be one of the most exciting trends in technology development. Such processes might be the starting point for new alliances between local communities, NGO's and multinational firms to address the needs of BoP users at lower prices and adapted to unreliable energy systems, and the lack of transportation or communication infrastructure. Technology development in these conditions is challenging indeed; there are important constraints and requirements that need to be addressed for any technological development to succeed. However, innovative technologies have a central role to play in the effort to alleviate poverty in this world. The potentials are much larger than the challenges, as the case studies from fields as diverse as agriculture, renewable energy, disaster risk reduction, ICTs and human settlements, in this publication encouragingly show. Academia, civil society, local communities, governments, NGOs and industry need to increase collaboration and form effective partnerships in order to identify innovative solutions that are able to reduce poverty and lead the way towards more sustainable development at a global level.

This publication reflects on the outcome of the 2012 EPFL UNESCO Chair International Conference on Technologies for Development. It is structured into four sections of which the introduction is the first part. The papers in the second section focus on the question of appropriate technologies and in particular on the needs and participation of the various stakeholders. The third section investigates questions related to sustainable integrated development. Finally, the papers in the fourth section illustrate the need for empowerment, knowledge sharing and the role of innovation.

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[3] The term 'Bottom of the Pyramid' (BoP) suggests that multinational companies can make substantial profits by selling to the poor while at the same time help eradicate poverty (Prahalad 2006).

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Part II
What is an Appropriate Technology?

Chapter 2
The Role of Science, Technology and Innovation Policies and Instruments for a Paradigm Shift Towards Sustainable Development

Lídia Brito

Abstract There is an increased recognition that Science, Technology and Innovation (STI) can spur inclusive and sustainable development in multiple ways. For STI to be a driver for sustainable development it is important that Development Agendas are people-centered, creating an enabling environment for the power of STI to be a harness for development. This implies that countries and regions have to develop, implement and monitor their national and regional STI policies and programs that promote knowledge production, dissemination and utilization as well as the development and appropriation of technologies that spur innovation not only at large production facilities but also at grassroots level, involving small and medium enterprises (SMEs), as part of a broader development agenda. These frameworks require that special attention is given to human capital development, a fundamental block of any sustainable development agenda, and to governance mechanisms that promote broader participation in decision making in STI related issues, in particular promoting the participation of vulnerable groups such women, youth, Small Islands Developing States (SIDS) and indigenous people. This paper argues that STI policies need to be transversal, cross–cutting policies that support and build the structural pillars for sustainable development and through dialogue, engage the wide range of development stakeholders. It also explores the ways UNESCO intervenes in this strategic area for development through the design, planning, formulation, monitoring and evaluation of national and regional STI strategies and policies (including reforms), as well as thorough building the national and regional capacities in science and in public policy development, and the development of national, regional and global fora on STI and development.

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2.1 Introduction

In today's highly interconnected world, human beings, as part of the biosphere, are considered the major force impacting our planet; therefore, the human species is facing a crucial transition period. In this uncertain stage of human history, vulnerabilities and risks are high but also are opportunities for socio–ecological changes and transformations. What is important is that global sustainability becomes the foundation of our interconnected and interdependent global economic, social and environmental systems.

The reality, however, is that we still promote a model of development based on the premises that development is a process of structural changes that will imply a series of historic steps that developing countries have to follow in order to move from a traditional society to a more modern one in order to reach the present levels of mass consumption of developed countries. This model assumes that industrialization is the main driver of growth, and consequently the degree of development is essentially measured by levels of production and consumption, using indicators such as Gross Domestic Product (GDP) and per capita income, ignoring other relevant information such as social equity, life expectancy at birth, redistribution of wealth, access to educational and health systems, absence of violence, environmental sustainability and other indicators that measure better the improvement of living conditions and welfare of all.

It is in this context that concepts such as *Knowledge Economy*, defined as an economy where "the generation and the exploitation of knowledge have come to play the predominant part in the creation of wealth" (DTI 1998), gained root and became the paradigm of most of the interventions in the field of Science, Technology and Innovation (STI).

However it is clear that with the financial, energy, food and environmental crisis that the world, as a whole, is facing nowadays, a paradigm shift will have to occur, in particular in economies that are extremely vulnerable to global trends and issues such as the economies of the Least Developed Countries (LDC) and Small Islands Developing States (SIDS), in particular in Africa.

It is high time to acknowledge that integrating environmental, educational and social issues into economic decisions is vital to humanity. It is time to reaffirm that economic and financial crisis cannot be solved without deeply transforming the way we consume, we produce, and we interact with our planet.

Clearly, part of the problem rests in the fragmented and restricted analysis on which we base our decisions, in the predatory nature of the globalization process occurring today, and in the fact that local problems need more and more global solutions.

In order to address the causes of the present crisis it is important to look at knowledge in a different way, not only as a driver for the economy but as the main driver for the empowerment of the people in the different societies. The concept of *Knowledge Societies*, defined as societies that have a culture of science and use knowledge to act, is therefore a better one to use when discussing STI and development, but unfortunately is still only part of the discourse and rarely integrated and used in the design of policies, programs and interventions. It is needed that alternative models for development are discussed and that they integrate concepts, such as the one on sustainable societies, concepts that supports the paradigm shift from a knowledge economy to knowledge societies.

These alternative concepts of development defend that we should think in the diversity of sustainable societies, with economic and technological options that are differentiated, that are geared towards a harmonious development of the people and their relationship with the natural world, clarifying the boundaries of a new ethical behavior in the relationship between nations and its people, and placing the common good in the front of development interventions.

In itself this implies that more than one development model is needed, and that nations and regions should choose models that are interlinked and interdependent and that reflect visions of the world that are locally relevant and culturally appropriate.

In that sense we are talking about development models that are people-centered and inclusive; models based on local realities that take advantage of local knowledge and innovation capacities; models that start from the country's potential to solve both local and global issues and that strives to create a culture of ingenuity, science and technology. Models that capture the complexity of our development challenges and the dynamics of the natural environment we live in. It implies that we have to embrace the values, behaviors and lifestyles required for a sustainable future and in that process strengthen two critical drivers for development: ethics and empowerment. It is about building up conviction and commitment to pursue a better development path; it is about using diversity to sustain growth.

The concept of sustainable development has experienced an extraordinary rise over the past two decades and now pervades the agendas of governments, international organizations and corporations as well as the mission of educational and research programs worldwide. Although there are some earlier antecedents, these ideas had their formal appearance with the Brundtland Report, *Our Common Future* (1987) and the results of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Council for Science (ICSU) World Conference on Science (1999). At the same time a list of important and influential documents were published, showing the relevance of sustainable development within the global agenda (Clark and Dickson 2003; Kates et al. 2001; NRC 1999; Parris and Kates 2003; UNCED 1992) conforming the bases for the organization of a new research and innovation paradigm.

As mentioned in the State of the Planet Declaration (Planet Under Pressure 2012): "The defining challenge of our age is to safeguard Earth's natural processes to ensure the well-being of civilization while eradicating poverty, reducing conflict over resources, and supporting human and ecosystem health."

This is a clear challenge to science and engineering. For it requires building scientific and technical skills and to develop the social support to apply them (Brito 2005).

The international scientific community has an important role to play in finding alternative solutions to the development challenges of today. This has implications, it means that the scientific endeavour will have to integrate the different disciplines and move from interdisciplinary to transdisciplinary, to build the knowledge needed for finding more sustainable paths for the future.

It is interesting to see that sustainability science, as a new paradigm, has been applied more and more in the last decade and those large programs such as Future Earth are taking roots in the scientific community and growing. However, when we look at the distribution of research projects that have sustainability science at the core we realize that the African Continent is lagging behind, once again (Bettencourt and Kaur 2011).

Therefore, if we want a planet that will continue to develop and strive towards improved living conditions for all its citizens, sustainable economic growth and environmental sustainability specific policies, programs and actions that promote the production of knowledge, technologies and innovations needed for sustainable development have to be in place everywhere in the world.

These challenges pose important questions:

- What are the core scientific questions and issues that must be addressed in the decades ahead that will form the foundations for sustainability science, technology and innovation?
- What research strategies will be required to enable the scientific inquiry and facilitate the research to address these core questions of sustainability science?
- What kind of innovation strategies will be required to transform the human productive system worldwide to address the environmental and societal problems that the planet and life are facing?
- On STI Policies and STI Governance: (a) What systems of incentive structures—including markets, rules, norms, technological impact, and STI information—can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories? (b) How can today's relatively independent activities of research planning, monitoring, assessment, and decision support be better integrated into systems for adaptive management and societal learning?
- What innovations and changes will be required to more fully enable the institutions and infrastructure essential to the conduct of sustainability science and technology?

These are difficult questions that have to be answered if an enabling environment is to be created. Several concrete actions can be pursued to create the right environment for STI to play its role in development:

- Develop research and innovation policies that are cross–cutting and creating structural base for the other policies:
  - Strengthening science and engineering education at all levels;
  - Promote policy integration in the country, region and continent;

  - Improve and scale-up research and innovation programs in crucial and strategic areas for development;
  - Spur innovation in the productive sector, including small and medium enterprises (SMEs);
  - Popularize science and engineering in society.

- These traversal, cross–cutting policies should have associated with several instruments and mechanisms that promote policy implementation and the capacity to monitor and evaluate the impacts and the needs for new policies, such as:

  - Develop steering mechanisms: peer-review, financial instruments, institutional and research agendas linked to development agendas in the country and in the region;
  - Develop mechanisms to measure and produce high quality STI indicators;
  - Ensure the knowledge cycle in society (identification, production, transfer, appropriation and re-creation of knowledge) happens by building the critical mass in society through actions in Higher Education Institutions, including Engineering Schools, science education needs to be reinforced at all levels and stronger partnerships between universities and industry are needed.

- Build **Networks of Excellence** that ensures knowledge production and identification of existing knowledge. Implying that the Centres do more than sharing ideas, but move towards a common research agenda, have more human capacity and more resources, building synergies for institutional sustainable growth within Africa and with other parts of the world and allowing for:

  - Deep understanding of factors influencing global policy making processes;
  - Capacity to contextualize the policies at national and regional level;
  - Capacity to critically analyze impacts;
  - Capacity to develop alternative policies.

- **Building bridges between development actors** by mobilizing the social energy around a common vision of development, developing the social contract with science through the supporting endogenous capacities and by using diversity to sustain development.
- **Build ownership and commitment:** engage local stakeholders in the design, implementation and resources mobilization by including society in the Networks of Excellence through:

  - Building Centres of Excellence that are embedded in the society;
  - Build partnerships frameworks between the scientific community, Government, productive sector and civil society;
  - Develop link between knowledge-technology and practical solutions to everyday problems;
  - Developing local industry through promotion of partnerships and access to knowledge.

- **Fair trade:** negotiate better intellectual property rights and market conditions.

Policymakers need to have a better picture of their national, regional and global performance with regard to the distribution of knowledge and to estimate the magnitude of the loss of potential innovation due to the limitation of the STI policy instruments which are applied. In this context, a better understanding of the long-term evolution of STI policy institutions and organizations as well as their governance characteristics is also needed.

As a specialized agency of the United Nations (UN), UNESCO contributes to the building of peace, the eradication of poverty, sustainable development and intercultural dialogue through education, the sciences, culture, communication and information. In fulfilling its mission, UNESCO will carry out for the international community its five established functions: (a) Laboratory of ideas; (b) Standard-setter; (c) Clearing house; (d) Capacity–builder in Member States in UNESCO's fields of competence; and (e) Catalyst for international cooperation. To promote sustainable development, the UNESCO *Division of Science Policy and Capacity Building* is promoting two projects: the Global Observatory on STI Policy Instruments (GO→SPIN)[1] and the STI Global Assessment Programme (STI-GAP)[2]. The GO→SPIN platform is based on a recently designed methodology for the standardization and systematization of information on STI policies, policy instruments and indicators that provide new and revolutionary tools for knowledge–brokers, decision-makers and STI policy experts. STIGAP is being prepared with the objective to develop a global dialogue on data collection that will result in the capability to better assess the development of STI at the international, regional and national levels. This assessment will enable the formulation of more appropriate recommendations on policy-making for Member States. Both initiatives not only fulfill the five functions of UNESCO, but also contribute for the generation, analysis, diffusion and sharing of adequate information about complex societal and nature systems. Contribute for the definition of strategies for science, engineering, technology and innovation which are the most valuable assets needed for the establishment of STI policies that can promote long-term planning for sustainable development.

Through UNESCO Chairs/UNITWIN Programme capacity development in higher education in developing countries is a priority and to support higher education networking is a strategy of UNESCO since the 1990s. The UNITWIN Programme has changed over time and it aims to impact socio–economic development effectively, generating new ideas through research and reflection, and facilitating the enrichment of existing university programs while respecting cultural diversity, by promoting transdisciplinary work and the role of the Chairs as

[1] http://www.unesco.org/new/en/natural-sciences/science-technology/sti-policy/global-observatory-on-policy-instruments/

[2] http://www.unesco.org/new/en/natural-sciences/science-technology/sti-policy/indicators-statistics-and-prospective-studies/science-technology-and-innovation-global-assessment/

"bridge builders" between academia, civil society, local communities, research and policy-making.

The UNESCO Chair in Technologies for Development, established in 2007 in the Cooperation & Development Center (CODEV) at the Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, fully plays the dual function of "think-tank" and "bridge-builder", effectively promoting transdisciplinary research technology adaptation through partnerships with local institutions, in order to develop innovative solutions for the most vulnerable populations.

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Chapter 3
New Vernacular Architecture as Appropriate Strategy for Housing the Poor

Sytse de Maat

Abstract Improving living conditions of the poor often involves a drastic change in lifestyle, in order to fit daily life into industrially produced dwellings. Slum rehabilitation programs replacing informal settlements with standardized mass housing, have often resulted in a mismatch of inhabitants and their built environment. Participation strategies meant to counter this problem, show little effect unless the user is in charge. What is the problem with development and participation? This paper will discuss 'housing the poor' as a case to illustrate how industrialization and systemization are at odds with participation. We will consider two ways of producing housing: industrial mass housing, and informal settlement. The focus is on the connectedness of the user, the inhabitant, with his dwelling. It will lead to the observation that participation aims at meeting the diversity that is natural to human beings, whereas systemization requires and produces the opposite: uniformity. Moreover, the term *user-participation* implicitly states the user is an outsider participating in developers' projects, which after all are dominated by the interests of the construction industry. An Appropriate Technology-approach in housing the poor would benefit from a focus on user-building interaction as it taps directly into people's most powerful resource: creativity. Western systemization is not the only route to improvement. Strategies based on vernacular are at least as effective, appropriate, and humanly sustainable.

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3.1 Introduction and Purpose

When your tool is a hammer, everything looks like a nail (Anonymous).

Improving living conditions of the poor often involves a drastic change in lifestyle, in order to fit daily life into industrially produced dwellings. Slum rehabilitation programs replacing informal settlements with standardized mass housing, have often resulted in a socio-cultural mismatch of inhabitants and their built environment. This phenomenon shows resemblance with capital-intensive development aid that sparked the Appropriate Technology-movement in the 1970s, which called for prioritizing people over production. In urban strategies today, user-participation has resulted in Appropriate Technology-concepts like 'action urbanism', 'action design', 'social production', 'regenerative design and development' and 'user-driven development.'

The term 'user-participation' however, implicitly states the user is an outsider participating as a guest in the designers' and builders' projects, which after all are dominated by the interests of developers and the construction industry. The gap between the user's informal economy and the developer's capitalized economy makes many housing-the-poor projects eventually non-appropriate.

Apparently, rehabilitation programs, development projects, appropriate technology, and user-participation do not all move in the same direction and sometimes even collide. One could even say that development and participation have opposite objectives. The purpose of this paper is to identify the underlying pattern of conflicting interests, and to find a common focus that could serve as a shared ambition.

3.2 Design and Methods

This paper will discuss 'housing the poor' as a case to illustrate how industrialization and systemization are at odds with participation. To do this, we will consider two ways of producing housing; one is industrial production of mass housing, the other is informal settlement. The focus will be on the user, the inhabitant. Next, we will discuss the distinction between housing for personal use and housing as a commodity made for the market. It will bring to bear the value of vernacular architecture as a housing strategy, free of the restrictions that come with systemization. It will lead to the observation that participation aims at meeting the diversity that is natural to human beings, whereas systemization requires and produces humanly inadequate uniformity.

This paper is written as part of research on the role of bodily interaction with buildings in bonding with the habitat. Thorough understanding of how built structures are used by their inhabitants as instruments for well-being, living, and livelihood, lies at the base of appropriate strategies for housing the poor.

It is the author's belief that the bodily interaction of the user with his environment is essential in environment cognition and place attachment. The research aims at testing the hypothesis that satisfaction with the built environment is an existential issue that gains from (instrumental) bodily interaction. *Appropriate Technology, Needs and Participation* refer to appreciation of the role of the user, and in order to understand that role, we have to study the fundamentals of how people relate to their environment. Once we understand these, we can give meaning to participation.

Literature study has focused on: (1) how user-building interaction has developed under mechanization and systemization; (2) how bodily interaction is part of environmental perception; (3) how bodily interaction supports habitat cognition on an existential level. The first of these focuses will be leading in this paper.

3.3 Results

Before discussing how industrialization and systemization are at odds with participation, we will make some comments on the concepts of poverty and sustainability in order to reveal unexpected potentials that lie hidden in informal settlement.

3.3.1 Poverty

In considering ways to reduce poverty, it is important to note some obstacles in measuring poverty. These obstacles not only hinder proper assessment of the extent of poverty, they also obscure vision on the real needs.

First, in developed countries assets can be precisely measured through property systems such as cadastres, vehicle registers, bank accounts, etc. In developing countries however, such systems function less well as they are either poorly developed, inadequate, too complicated, or not accessible for the poor. A basic issue such as illiteracy already has a crippling effect on the access to formal property systems. As a result, many of the assets possessed by 'the poor' are invisible in the statistics. Much capital and wealth is thus not measurable and therefore considered not present. The blanks in the statistics are easily interpreted as zeros. Research has shown that this invisible capital and its subsequent potentials are of considerable extent (de Soto 1989, 2000). Part of poverty comes from the immobility of such capital and economic strategies like land titling aim at bringing capital to life.

Second, the picture of poverty is distorted by the emphasis on financial resources and the overlooking of the greatest resource of all – individual initiative. Lower-income owner-builders are more capable of satisfying housing needs than institutions tend to assume (Grenell 1972; Grindley 1972; Neuwirth 2005). In addition, the preoccupation with economic value diverts the attention from other reasons for satisfaction found in urban slums, such as valuable social networks, strong sense of belonging (Fried and Gleicher 1961; Mehta 2004), or the existential value of fulfillment of man's need to utilize his internal resources (Rapoport 1969).

Third, from the wealthy point of view, informal settlement is an expression of poverty as its appearance does not meet the aesthetics of the well-to-do. No matter how much money is going around in the informal economy, its looks, its chaotic appearance, its informality, are all qualities that do not match the image of systematic order and thus the power of the establishment. Labeling informal settlement as poverty that should be reduced, is part of sustaining the aesthetics of high technology. Charity is an activity of the higher classes that, besides helping those in need, serves the expression of their power (Veblen 1899). Although class systems may in general have escaped our attention, the mechanism lives on in the concept of developing aid. The novelty of appropriate technology was that it challenged the superiority of advanced technology.

3.3.2 Sustainability

Providing sustainable solutions in development aid is an honorable ambition, as it is clear that the ecology of the planet needs protection. In the case of reducing poverty however, the challenge is twofold. Not only should the future situation be more sustainable than primitive industrialization, chances are that 'development' will bring something less sustainable than the existing situation. High densities result in short distances, low car ownership, and efficient use of amenities and resources (Brand 2010). Much of the present relatively small ecological footprint comes from the close coherence of all aspects of living in informal settlement. Moreover, the sustainability of developed areas may be dependent on informal settlements. In Mumbai for example, squatter areas host a highly effective recycling industry.

3.3.3 User-Building Interaction Under Mechanization and Systemization

A way to assess a country's level of development is to look at its degree of systemization. In developed countries, local systems are highly interconnected and facilitate interlocal interaction. Borders between systems are easy to cross. The further systems are integrated, the easier people can interact. In developing countries the interconnection of systems is limited, which keeps people from operating outside the local circle (de Soto 2000). At the same time, systemization is a key ingredient of industrialization and capitalization and much of the West's material and financial wealth is created by means of systemization. The problem with high-tech development aid is its misfit with the local level of systemization, and appropriate technology strategies aim at finding the right fit (Akubue 2000; Willoughby 1990).

Systems work best when simple, and for that they need standardization of input and output. Systemization's need for uniformity comes from its inability to deal with diversity. A fundamental problem in industrialized production is that mechanization and standardization cannot handle the diversity of the organic (Giedion 1970). Not only the physical diversity of human bodies is contradictory with standardization, social and psychological differences are not suitable for one size-fits-all either. In other words, user's autonomy [self-determined] as in participation, is incompatible with the heteronomy[1] [other-determined] of systemization (Turner 1976).

A natural way of dealing with diversity is creativity. It allows us to respond to a potentially infinite range of phenomena, and creativity generates a sense of control and a feeling of accomplishment. Dealing with diversity puts us in contact with the world; it helps us feel who we are. Unlike that, creativity's counterpart systemization alienates us from our self. This feeling of alienation is what brought the call for user participation in urban planning.

Participation is about the degree of autonomy of the dweller, and 'Dweller Control' is a perspective that radically prioritizes that autonomy. John Turner in the 1970's developed several 'laws', of which the first states that: "When dwellers control the major decisions and are free to make their own contribution to the design, construction or management of their housing, both the process and the environment produced stimulate individual and social well-being. When people have no control over, nor responsibility for key decisions in the housing process, on the other hand, dwelling environments may instead become a barrier to personal fulfillment and a burden on the economy" (Broome 2011; Turner et al. 1972).

In rehousing programs, a common strategy is the industrialized mass production of dwellings, often stacked in high-rise. The advantages of high-rise are limited. For one, building higher than five storeys barely contributes to more efficient land use (Correa 2008). Daily power cuts, even when scheduled, are a serious problem for those living on the higher floors where elevators are indispensable. Lack of maintenance of building services, which tends to come with low cost housing, is as problematic. Social cohesion suffers when homes are stacked, as the perceived distance to neighbors on a different floor is bigger than to those next-door. Studies show a negative effect on mental health (Alexander 1977). Moreover, combining household and work is easier in ground bound dwellings, and much livelihood simply requires direct access at street level.

[1] Immanuel Kant defined heteronomy as: an action that is determined by some outside influence (i.e., some force other than the freedom given by practical reason, such as inclination) impelling the subject to act in a certain way (cf. autonomy) (Palmquist 2000).

Industrialized housing production inevitably comes with standardization, which often results in dwelling layouts that are literally of average fit with inhabitants needs. At best, the design contains certain flexibility, which means that a solution serves several needs through offering a compromise, in itself a symptom of the inability to provide housing that meets user's demands (Forty 2000; Hertzberger 1991). In informal settlement, large social networks and extended families are common patterns and these are reflected in the built environment. Built structures are being changed continuously to fit and keep up with diversity.

This process of adjusting is part of the interaction of users with their environment, and contributes to their attachment with it. Improvements and decorations are reflections of the self of inhabitants. It goes without saying that making such adjustments in concrete high-rise is near to impossible. Not only the physical properties of reinforced concrete will keep users from making things fit with their lives, so will formal conditions. Building codes, shared property statements and lease contracts do not favor individual initiative. Especially rented housing limits adjusting to zero. This way, humans are forced to adapt until they themselves meet standards. The same goes for families, which, contrary to the culture, are trimmed to the standard format called the nuclear family (Lang 1989). Le Corbusier's '*machine à habiter*' (1992) is in many ways a valid metaphor for Modernism.

On an urban scale too, planning and engineering tend to create environments that restrict rather than facilitate diversity. Rahul Mehrotra described Mumbai as a disconnection of the *Kinetic City*, which is the city of living, using, the users, adaptation, and festivities, and the *Static City* of planners, urbanists, architects and engineers (Mehrotra 2009).

3.3.4 Effects of Industrialized Building Production

Miserable housing conditions automatically become part of the economic weaker section of society, as the short supply of proper housing leaves those without the money empty handed. This shows clearest in countries with high-income disparity. In countries with more level incomes like Japan, the burden of housing shortage is spread more evenly. For example, many commuters spend the night in hotels during the week and return home in the weekend making homelessness a part-time condition of which even executives suffer (Kerr 2001).

Following the market mechanism of supply and demand, the demand for housing is answered with mass production of low-cost dwellings. Production of uniform units in large quantities is used to reduce costs per unit and this uniformity demands the exclusion of the individual future inhabitant, the user. For optimal return on investments, housing should be as average as possible and changes should only be made in the interest of capital. User-building interaction is translated into functionalistic concepts, based on the deterministic idea that a certain design goes with a certain behavior. The idea that people have to be able to adjust their dwelling in order to make it their home does not fit with standardization. User's individuality is contradictory to mass housing.

Preliminary field research in informal settlement has shown that developers can meet resistance when inhabitants cannot recognize themselves and their way of living in proposed rehabilitation projects. Dwellers even expressed their preference for informal settlement over industrially built mass housing.

Similar effects can be found in today's high-tech office buildings, which show a trend towards technical autonomy and exclusion of the user. Doors open automatically, lighting, heating, and ventilation are managed centrally. User-building interaction is brought to a minimum in the name of comfort, energy saving, and sustainability. As a result, users experience a lack of sense of control, consequent stress, and a general inability to feel at home.

3.3.5 User Participation, a Call for Creativity

Experiences with too uniform mass housing have led to the call for user participation in the planning process. The aim is to bring back the character of the individual user in the design. In understanding the potential reach and limitations of participation, it is important to recognize who has the authority and knowledge to change the design and the built structure. This authority to change is an essential condition for the user's creative interaction with the habitat. Ultimately, in true user participation the user would have that authority. In any development however, the reality is that the stakeholder who takes the highest risk is always in charge, and the highest risk is on whoever makes the biggest investment. Thus, prioritizing economic value over the interests of the user marks all projects in which stakeholders are related to each other in a market fashion. Only when the user himself makes the biggest investment, this market interference can be avoided.

The concept of users being in charge of construction is part of several successful strategies. Studies in the United States have shown that owners-builders are well capable of producing satisfactory housing in the lower economic section of society by bringing in their own initiative, ingenuity, and energy and thus avoiding the financial burden that comes with outsourcing (Grindley 1972). Another strategy, sparked by the ideas of J.F.C. Turner in a working paper for a 1966 UN seminar (Turner 1976), is the scheme of 'site and services' in which land plots are sold within the economic reach of the poor, including the utility services that require neighborhood scale investments. The new owners can develop their home according their own ideas and resources. 'Site and services' is based on the recognition that most poor families built their own shelter. Several factors contribute to its success. First, full room is given to user participation, which helps to avoid the misfits resulting from industrialized production. Second, the actions involved in creating, operating and using the building contribute to the user's feeling of accomplishment, sense of belonging, attachment, and ultimately establishing a dwelling that is a reflection of the self. This strategy was developed in India by Christopher Benninger and later adopted by the World Bank. The success of these low intervention strategies compared to industrialized production or capitalization-based solutions, brings forward an alarming extrapolation: might informal settlement be a solution rather than a problem?

Informal settlements routinely get bad press and are often deliberately referred to as slums. Even though research is showing that crime rates are relatively low, media keep building the opposite image (Neuwirth 2005). Despite the tight knit social networks and the strong social control that come with high densities, squatter settlements are being portrayed as places of chaos and anarchy. Behind this wall of bad publicity however, live a billion squatters in self-created dwellings making optimal use of means and resources. The communities show normal social order where people care about their children, each other, and the neighborhood. Their informal economy is of considerable proportions and is indispensable for the formal economy. Their way of dealing with housing shortage deserves recognition as it shows that housing improvement by users themselves is often more desirable than top-down imposed replacement (Brand 2010; de Soto 2000; Neuwirth 2005; Mehta 2004; Turner 1976).

The above shows how user-building interaction and all variety and adjustment that come with it, is at odds with the capital driven market economy. In order to make something sellable on the market, one should not be emotionally attached to it, i.e. it should not be a reflection of one's self. User satisfaction and attachment with the environment however, call for the opposite: focus on use and creativity, away from uniformity and commodity. In order to reduce poverty, appreciating this attachment is an important instrument as it taps into more resources than only the material and systemic. Individual initiative and the involvement of one's own hands in creation of the dwelling add existential values that are unknown to industrial mechanical production (Alexander 2002; Pallasmaa 2009). Moreover, satisfaction is simply greater as "Deficiencies and imperfections in *your* housing are infinitely more tolerable if they are your responsibility than if they are *somebody else's*" (Ward 1976).

An alternative approach today is New Vernacular Architecture as described by Frey (2010), in which architects and planners participate in the world of the users and their builders. It is marked by horizontal exchange of expertise and based on economic equality. Its appropriateness lies in its match with the realities outside the economy of commoditization and capitalization, hence the term *vernacular*.

To start with, the ultimate appropriate building technology in a given setting is the local technology already in use for a long time, i.e. vernacular architecture. Vernacular is generally distinguished from high-style architecture, which aims at being innovative and breaking with the past. Anthropologist Amos Rapoport reviewed and redefined the term *vernacular* by sets of product characteristics and process characteristics (Rapoport 1990). Frey however, uses Ivan Illich' interpretation of (Du Cange 1736) to distinguish vernacular from design architecture: "[vernacular] designates the inverse of a commodity. 'Vernacular' means those things that are homemade, homespun, home-grown, not destined for the market, but that are for home use only" (Illich 1983).

By doing so, Frey describes logic about vernacular architecture that has parallels with Hernando de Soto's logic about the creation of capital. Both authors refer to the distinction of use versus commodity. The mechanism that moved architecture from vernacular to commodity is industrialization, which plays the role that property systems have in capitalism. The processes and effects of the transition towards design architecture are mainly those of the division of labor and the subsequent alienation of the craftsman and his work. Frey points at the many qualities that get lost in this transition, and aims at bringing back the qualities of vernacular into the architecture of today: "The aim is to distinguish the practices that most radically and clearly prioritize respect for human criteria (individual and social), for the environment and for architecture."

The terms Appropriate Technology, Needs, and Participation all refer to the user and thus have a focus that is unlike the focus of systemization. However, as already mentioned, participation can be seen as part of systemization in the sense that it tries to have users participate in the system. If a contribution to the life of the user were the aim, participation should work the other way. Experts would participate in the life of users, and have their focus on users' interaction with the habitat, illustrated in Fig. 3.1. Thus, new vernacular can be seen as a redefinition of participation.

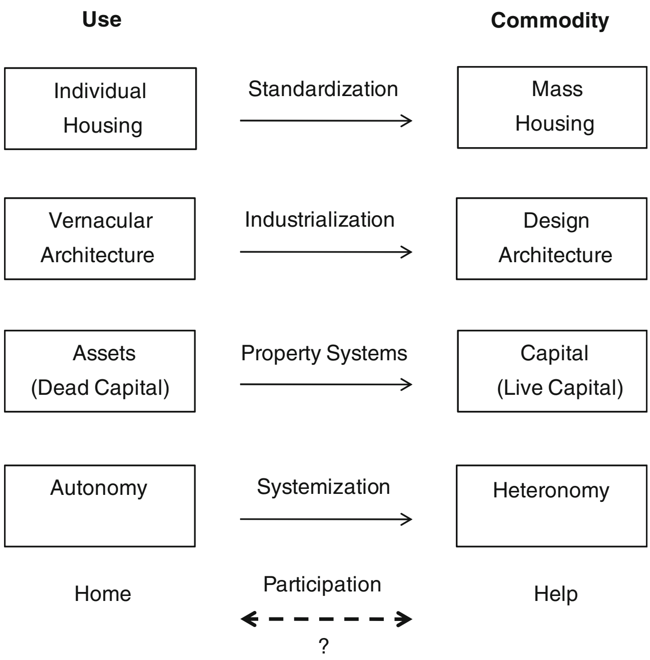

Fig. 3.1 The ambiguous meaning of participation

3.3.6 Bodily Interaction as Part of Environmental Perception

Through the above, *user's interaction with the habitat* appears as a new focus for a shared ambition in development and reduction of poverty. In the following paragraphs, the meaning and role of bodily interaction is explained briefly.

Since the Enlightenment, the notion that there exist five senses seems to have been generally accepted. Touch, the fifth sense added by Aristotle however, kept generating confusion. Touch had no organ like eye, ear, nose or mouth and the skin was not considered a sense organ. Moreover, it was understood that touch in fact involved five sensations: pressure, warmth, cold, pain, and kinaesthesia (sensibility to motion) (Bloomer and Moore 1977). This division shows what sensations are experienced through which organs. Yet, it does not show how sensation contributes to our understanding of the world. Environmental psychologist J.J. Gibson arranged the senses into roles in the context of perceptual systems. This way, senses can contribute to each other, which allows active perception. The eyes provide information by which the hand can be sent out to touch and investigate the environment. Legs can be moved to give the eyes a different perspective (Gibson 1962; 1986; Mace 1977). In addition, Gibson considers incoming and outgoing signals in the nervous system as output and input in the perceptual system. Output was further divided in exploratory and performatory, as was input divided in imposed and obtained (Gibson 1983).

Via these systemic bifurcations however, we can think of bodily interaction with built form as a process in which all senses and all aspects of perceptual systems are involved. For example, by opening a door we perceive its heaviness, its structure, its resistance, its sound, the resonance of its sound, the acoustics of the room, etcetera. Our performatory action is exploratory; our kinaesthetic proprioception is a means of perception. By creating, using, and even destroying a building, we get to know its character. The lack of interaction is why we lose contact with our buildings in today's high-tech architecture and as we have become so detached from our buildings, we find it hard to understand how squatters and informal settlers can appreciate their dwellings so much that they prefer not to move to buildings of 'higher standards'. An eye for this close relationship can guide us towards an appropriate strategy to reduce poverty.

3.4 Conclusions

Systemization being the main development tool in the West may be the hammer that makes everything look like a nail. Participation is such a nail. It is thought of as affording systemization, whereas the user has no direct interest in being systemized. On the contrary, from humanitarian interest, technology and systemization should be no more than servant to people, meaning that experts offer their services as participation in the lives of dwellers, unlike the concept that dwellers are allowed to participate in the processes governed by outsiders. This New Vernacular approach is a tool many people are familiar with, not a hammer.

In this paper, it is suggested that an Appropriate Technology/New Vernacular approach in would benefit from a focus on user-building interaction as it taps directly into people's most powerful resource: creativity. Moreover, it helps avoiding the inevitable mediocrity and inadequacy of mass production solutions. It may require moving in unconventional directions, away from functionalism, and efficiency, towards architecture of use, of the home, onwards with building as a life form in symbiosis with the user.

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Chapter 4
Computerization of Medical Consultation for Children Under Five Years of Age in Rural Areas of Burkina Faso

Guillaume Deflaux, Thierry Agagliate, Jean-Etienne Durand and Pierre Yamaogo

Abstract The Integrated Management of Childhood Illness (IMCI) is a diagnostic method and strategy developed by the World Health Organization (WHO) aiming to reduce the morbidity and mortality of children under five years of age. Adopted by Burkina Faso, its implementation in rural areas of the country is difficult due to an insufficient number of trained health workers and because difficult working conditions increase the lack of rigor and motivation. Terre des hommes Foundation partnered with the software editor Wopata to develop a diagnostic support tool based on the IMCI directly intended for health workers. The Electronic Consultation Register (Registre Electronique de Consultation, REC) guides the health professionals throughout the consultation to help them strictly apply the IMCI, thus decreasing the number of diagnostic and treatment errors. It determines in real-time the illnesses of the patients as the health worker identifies the symptoms, and also the treatment associated to each diagnosed illness according to the IMCI, as well as the medicines to be prescribed with their dosages. By integrating the REC into the health system in rural areas of Burkina Faso we are affecting all the stakeholders of the health system. We are able to participate in the improvement of patient care, to ease the work of field agents and to allow the Ministry of Health to better monitor the implementation of its national strategies, and, ultimately, to save more lives.

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4.1 Introduction

In 2000, when the African Nations set the objective of reducing child mortality by two-thirds by adhering to the Millennium Development Goals (MDG) by 2015, they knew that such an objective would not be reached unless the primary healthcare system became both more accessible and more effective.

According to the World Bank, in 2010, in Burkina Faso, one in six children died before the age of five, due precisely to a lack of access to operating health services. Yet, most of these deaths are linked to a limited number of pathologies that are perfectly treatable: Malaria, Diarrhea, Acute Respiratory Infections, Measles and Acute Malnutrition. In order to ease the diagnosis and treatment of these pathologies, the World Health Organization (WHO) in collaboration with UNICEF and other institutions, developed in 1990 the Integrated Management of Childhood Illnesses (IMCI) strategy directly aimed at health workers. This protocol is a simple but systematic approach to diagnosis. IMCI has been adopted by most of the African countries.

Despite the significant funds allocated by States and international agencies for training each year, IMCI is still rarely part of the daily practices of health personnel in the field. An audit of the General Directorate of Family and Health of Burkina Faso has recently acknowledged this situation. Convinced that innovative solutions can be used to solve the lack of implementation of the IMCI, Terre des hommes (Tdh) is currently testing three of them in Burkina Faso.

The first one concerns the lack of access to health services by children less than five years of age. Since 2008, Tdh introduced fee exemption in the health districts of Tougan and Séguénéga for children under five (covering over 80,000 children). This mechanism led to the increase of the number of new contacts per inhabitant per year from 0.45 in 2007 to three in 2011.

The second axis of Tdh's intervention tackles the issue of the motivation of the health workers and of their interest in the results. Following an initiative from the World Bank, the Ministry of Health has tried Performance Based Financing (PBF) since 2011. Tdh joined the initiative in order to promote mother–child health qualitative and quantitative indicators.

Finally, Tdh addresses the issue of the rigor needed to effectively apply the IMCI protocol by introducing information technologies in rural areas. In collaboration with the French software editor Wopata, Tdh developed the Electronic Consultation Register (Registre Electronique de Consultation, REC), a simple and low-cost IMCI diagnostic support tool, in order to help health workers respect each step of the IMCI protocol.

This paper will present the main challenges faced during the development of the REC and how its functionalities make it a sustainable tool in environments a priori adverse to information technologies. This paper will also address the current limitations of the system and foreseen research tracks.

The REC is currently deployed in 11 health centers across two health Districts and will cover 75 centers in three Districts by May 2012.

4.2 The Burkina Faso Context

The analysis of the context in which the REC would evolve allowed the authors to define the main constraints with which the system had to comply. The analysis was done through on-site visits to health centers of Tougan and Séguénéga Districts, where the REC was to be installed, by the software engineers, medical doctors and IMCI experts. The authors were able to identify a large number of constraints that can be classified as follows.

4.2.1 Infrastructure

The rural areas of Burkina Faso suffer from a consistent lack of electricity. Even the villages connected to the electrical network cannot rely on it since the power is more often off than on. The only abundant and reliable source of energy is solar. Unfortunately, the solar systems that can be installed at the level of a health center can only provide power for a limited number of electrical devices. A low-power consumption device would be needed for the REC.

The mobile telecommunications network of Burkina Faso covers most of the country. People living even in remote areas are able to use mobile phones. Nonetheless, the network is still not equipped to support a proper internet connection. Under these conditions, the REC cannot be used as a centralized web application available directly from the internet. Instead, the REC would need to be installed locally, in each health center.

4.2.2 Health System

The main challenge faced was the integration in the National Health System. The REC had to be able to seamlessly replace the existing IMCI forms.

The health system of Burkina Faso is a complex administration and service provision entity with health centers in rural areas, district offices, rural hospitals, specialized hospitals, etc. When considering the installation of the REC, Burkina Faso's health system can be represented as a 3-1evel tree structure with, from top to bottom, the Ministry of Health, the health Districts and the health centers. The REC is installed at the lowest level where the patients are actually seen by the health workers and at District level for data consolidation. Figure 4.1 illustrates the system's structure.

The same tree can be used to represent the way data is centralized upwards.

Because of the lack of connectivity mentioned previously, the authors conclude that they will need to set up a completely decentralized network of instances of the REC that require a backup procedure on external storage devices, i.e., physically transporting the data to parent the node.

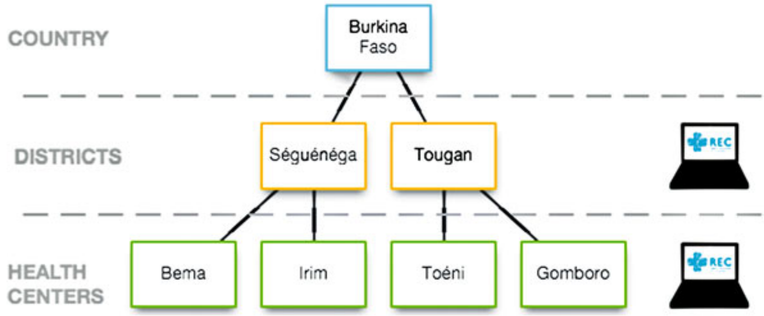

Fig. 4.1 Structure of the health system in rural areas of Burkina Faso

The issue of maintenance is also crucial in order to properly integrate the REC in the National Health System.

4.2.3 *Health Centers*

The districts where the REC is implemented also profit from the fee exemption for children under the age of five years, resulting in an increased number of patients daily. In certain periods of the year, the number of patients can reach 60 per day. The application of the full IMCI protocol can easily take up to 20 min per patient for a well-trained professional, the most time consuming tasks being the paper work, manually determining the diagnosis using the IMCI lookup tables, and establishing the prescription with proper dosages for each medicine.

The reduction of the consultation time would therefore become central for the REC, especially since the consultations are done by health workers generally unfamiliar with computers.

4.2.4 *Climate*

As many other African countries, Burkina Faso is a very hot country, where temperatures can reach up to 50 °C in the summer. These temperatures, combined with the humidity and the omnipresent dust, define quite a hostile environment for any electronic device.

4.3 The Diagnostic Support Tool

In order to tackle the issue of poor or incomplete IMCI diagnostics, a web application was developed as a diagnostic support tool directly used by the health workers (see the list of technologies in Table 4.1).

Table 4.1 Technical specifications of the diagnostic support tool

Element	Technology
Programming language	Ruby 1.9.3
Web application framework	Ruby On Rails 3.0.1
Database management system	SQLite 3
Compatible browsers	Google Chrome

The application guides the health professionals throughout the consultation to help them strictly apply the IMCI protocol, as shown in Fig. 4.2. Considering possible limitations of the end-users, the focus was to keep the application as simple as possible. The application is therefore based on a 3-step workflow: examine the patient, evaluate the patient and treat the patient.

The application includes the diagnostics for each IMCI age group (newborn, infant and child). The selection of the correct diagnostic form is done automatically as the user inputs the date of birth of the patient. The sequential approach of the IMCI has been completely integrated in order to allow for determining in real time the illnesses of the patients as the health worker identifies the symptoms. As the IMCI requires, if the answer to a previously informed symptom is modified, the health worker will have to resume the diagnostic from that symptom.

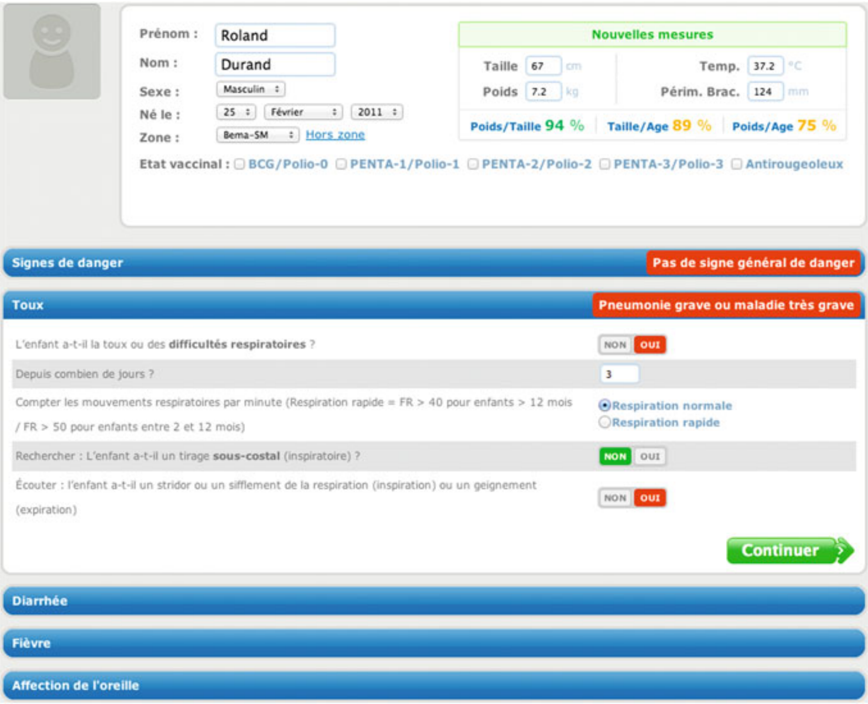

Fig. 4.2 The diagnostic form of the REC

Once the full diagnostic is established, the REC identifies the treatment associated to each diagnosed illness according to the IMCI. The medicines to be prescribed are supplied with calculated dosages, depending on the weight and age of the patient. Finally, the application allows agents to easily create a personal file for each patient containing the history of all diagnostics made and treatments administered.

If the symptoms are correctly identified, the REC can significantly decrease the number of diagnostic and treatment errors.

4.4 Managing the Context of Burkina Faso

The REC is not limited as a sole diagnostic support tool. It also provides key functionalities and features that make it operational within contexts with strong constraints as mentioned above.

4.4.1 User Friendliness

In addition to a simple workflow, the web application features a very simple interface resulting in an easy learning curve for users. The use of the keyboard is limited to entering the name and anthropological data of the patient. The rest of the data entry is done directly with the mouse, i.e., clicking. The data entry widgets are limited to text boxes, lists and yes/no questions. As a consequence, the necessary time to fill in and establish a full diagnosis and treatment goes down to a few minutes.

The ease of use of the application also helps mitigating the problems of the limited number of health workers trained on the IMCI protocol and the issue of staff turnover. The REC can be used by inexperienced health workers to perform IMCI consultations safely, as well as to train themselves.

4.4.2 Maintenance

The REC is installed on dedicated netbooks with a customized operating system (Tables 4.2 and 4.3 provide technical specifications). The only application running on the netbook is the diagnostic support tool. The operators of the system have complete control over the hardware and the software environments, simplifying maintenance operations.

The software maintenance is done entirely via pre-configured USB drives. According to the content of the drive, the operator can either re-install the operating system, install or update the web application, and even restore the previously

Table 4.2 Technical specifications of the netbooks

Element	Description
Brand	Asus EeePC
Model	10xx PE/PX
Processor	Intel Atom Series
Hard drive Capacity	250 GB
Screen size	10.1″

Table 4.3 Technical specifications of the operating system

Element	Description
Kernel	Linux
Base distribution	Ubuntu Netbook Remix 10.04

backed up data of a health center. No technical skills are required for these operations.

4.4.3 Secure Data Synchronization

Despite the lack of internet connection between the health centers and the Districts, the backup and consolidation of data is possible thanks to export and synchronization mechanisms via regular USB drives.

Each health center is provided with a pre-configured USB drive. The backup procedure is trivial: the health worker plugs the USB drive into the netbook and launches the synchronization process. The same operation is repeated at the level of the Districts, also equipped with a netbook. The mechanism allows each District to closely monitor epidemiological data across all health centers within their district. The backup process is done in parallel to the existing monthly reporting to the Districts. No extra travelling is required.

The content of the USB drives is encrypted using PGP algorithm, since they contain nominative data of the patients. Only trusted REC netbooks can read the USB drives.

4.4.4 Data Export and Analysis

Although the REC provides some statistics within the web application, the Districts often require performing advanced data analysis not suitable for the computing power of the netbooks. In order to ease this process, the REC provides anonymous data export in both SPSS and Excel formats.

Thanks to the analysis of data, the Ministry of Health is able to improve the supervision in the health centers and to focus its support on specific issues.

4.4.5 Energy Efficiency

The health centers benefiting from the REC have also received a solar power system in order to guarantee constant availability of the system. Nonetheless, power consumption was addressed by choosing netbooks equipped with low-power consumption processors providing a longer battery life, as opposed to regular laptops. In addition, the customized operating system is based on the Ubuntu Netbook Remix distribution specially designed to run on such processors.

4.4.6 Robustness

The choice of the Asus EeePC netbook was based on the recommendations of the Non–Governmental Organization (NGO) Inveneo. As specialists in deploying information technologies in difficult contexts, they had certified a similar model of netbook from the same brand.

This proved to be a good choice as only one of the 11 netbooks suffered from a major problem requiring its replacement over a period of 12 months.

4.4.7 Costs

The sustainability and extension of the REC to new health Districts is greatly dependent on the capacity of the State to provide the netbooks, USB drives, solar power kits and IMCI training to the workers. Table 4.4 summarizes the costs for the deployment of the REC in the 11 initial health centers.

It is important to consider the following:

- The REC Software Development is a one-time fee that will not be taken into account for any future extensions;
- No licensing fees are to be paid since the REC is built exclusively on Open Source technologies;
- In order to test the REC in the best possible conditions, Tdh has financed IMCI training for all the end-users of the REC. This will not be necessary in the future since the State of Burkina Faso is also training its agents, as the IMCI is a national strategy.

Table 4.4 Cost of the REC for 11 health centers

Element	Cost
Solar power kit	11 × 1,000 €
Netbooks	13 × 250 € (11 centers + 2 Districts)
IMCI training	15,000 € (50 health workers)
REC training	5,000 € (50 health workers)
REC software development	30,000 €
Tdh technical support missions	5,000 €
Total	69,250 €

4.5 Achievements

Over the 12 months between October 2010 and 2011, several supervision missions have brought to light encouraging results:

- Over 26,000 diagnostics have been recorded in the pilot health centers. Figure 4.3 shows the average number of diagnostics over time;
- Experienced health workers were able to train new ones on the use of the REC without the involvement of Tdh or the District;
- Health workers have repeatedly reported a decrease in the time of IMCI consultations;
- Only one hardware malfunction was reported.

The in-depth analysis of the data collected through the REC allowed Tdh to objectively evaluate the quality of the identification of the symptoms by the health workers. It was found that the respiratory frequency was overrated, probably to justify the prescription of antibiotics, and that the number of dysenteries was disproportionate as opposed to the number of dehydrations. Such findings suggest malpractices that can be addressed specifically during supervision visits in the health centers.

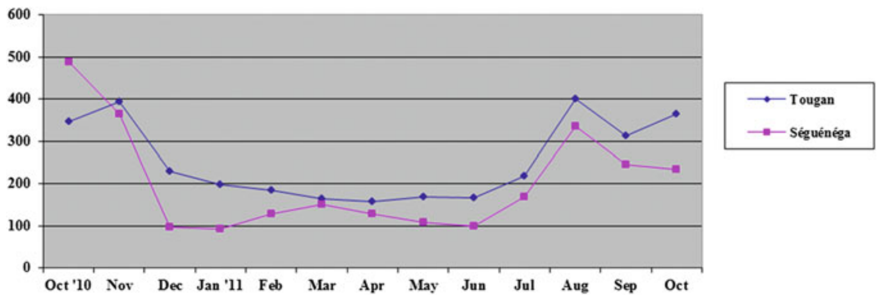

Fig. 4.3 Average number of diagnostics

4.6 Limitations

Looking back at Fig. 4.3 we can clearly identify two short periods of intensive use of the REC and one long period of moderate use. Several factors could explain this evolution; but, it is difficult to be sure of which one has the strongest impact. Users have reported not using the REC when the number of patients is too high, simply because the IMCI protocol remains longer than a regular diagnosis.

Does the first peak correspond to the enthusiasm of the launch of the REC? Does the moderate period between December 2010 and June 2011 represent a loss of motivation, delays in maintenance procedures, or a lack of supervision? Does the second peak correspond to the increase of visits to the centers due to the malaria season? It is difficult to determine.

The first year of implementation has been quite positive from the perspective of the introduction of new technologies in rural areas, but it is clear that the REC needs to be part of a more comprehensive supportive approach to primary healthcare. The combination of initiatives such as PBF and fee exemption is a good example.

4.7 Further Research

Several aspects of the REC can still be improved, and further research is already envisaged. The global user experience could be improved by porting the REC to tactile devises. It would ease the learning curve and limit the number of devices to one (the mouse is eliminated), for easier maintenance. With the improvement of the telecommunications networks, the REC could also benefit from remote synchronization avoiding the hassle of physically transporting the data to perform the backup procedure.

4.8 Conclusion

The integration of the REC in the health system of rural areas of Burkina Faso affects all the stakeholders, from health workers in the health centers to the decision makers at District and national levels. The REC is a system that has proven to be efficient in a difficult environment as an out-of-the-box alternative to the traditional IMCI forms. It assists in the improvement of patient care, to ease the work of field agents and to allow to the Ministry of Health to better monitor the implementation of its national strategies, and ultimately, to save more lives.

The promising results of Burkina Faso could easily be tested in other countries since the constraints identified are common to many developing countries.

Chapter 5
Field Investigations in Cameroon Towards a More Appropriate Design of a Renewable Energy Pico Hydro System for Rural Electrification

Bryan Ho-Yan, William David Lubitz, Cornelia Ehlers and Johannes Hertlein

Abstract Pico hydro (very small-scale hydro less than 5 kW) is recognized as a viable electrification option from economic, environmental, and social perspectives. Cameroon has significant hydro potential, yet low electrification rates. Inaccessibility, corruption and high trade duties inhibit pico hydro development within Cameroon. To help achieve greater rural electrification, a low head pico hydro system is being developed for local manufacture to overcome these barriers. Market research, site visits to pico hydro turbine and small wind turbine installations, collaboration with artisans, and end-user interviews were conducted in the South and Southwest regions of Cameroon. Six pico hydro and three small wind turbine sites were inspected, including both locally fabricated and imported systems. The uses of the electricity included general lighting, small media and cellular phone charging. Workshops were also visited and unguided trials were conducted with craftsmen to fabricate a turbine runner. End-users were informally interviewed regarding their experiences with pico hydro. Pico hydro in Cameroon is in its infancy stage. Both imported and locally manufactured products have been introduced to the region. Most required materials for turbine system fabrication were accessible. The success and longevity of locally manufactured systems requires robust designs and the establishment of local technicians and end-user training. In the event of failures, accessing replacement parts and skilled trades is a challenge for imported systems. End-users recognize the high costs of fuels and see pico hydro as a tangible means for electrification. Capacity for the local manufacture of pico hydro systems exist, however further training and resources are needed for the production of a competitive product.

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5.1 Introduction

Rural electrification enhances welfare through increased security, productivity, health, entertainment, information, and education (Independent Evaluation Group 2008). In Sub-Saharan Africa, only 29 % of the population is electrified. This percentage has been declining since 2001, as population growth has outstripped electrification over the past decade (International Energy Agency 2009).

Pico hydro, very small-scale hydro less than 5 kilowatt (kW) is recognized as a viable electrification option from economic, environmental, and social perspectives. The technology has low capital and operating costs (World Bank 2006), benign environmental impacts (Williams and Simpson 2009), and has good potential for local manufacture, promoting capacity development and inclusive growth (Maher et al. 2003). Pico hydro has seen enormous growth in Asia (Smits and Bush 2010) and modest success in Latin America, but meager performance in Sub-Saharan Africa. Cameroon has significant hydro potential, yet low electrification rates and inconsistent supply for dwellings that are electrified (Nfah 2009). Despite successes in other regions, barriers such as inaccessibility, corruption (Fonchingong 2009) and high trade duties inhibit pico hydro development within Cameroon.

To address the rural electrification concerns, a low head pico hydro system is being developed for local manufacture to overcome these barriers. This is part of an initiative by GREEN STEP e.V., an environmental education focused non-governmental organization (NGO) who has funded and installed pico hydro and small wind turbine systems and conducted training workshops in renewable energy systems in Cameroon. Field studies were conducted in urban (Bafoussam), peri-urban (Buea and Dschang), and rural settings (M'muock, Ndungweh, Lewoh, and Bafou) situated in the West and Southwest regions of Cameroon for problem contextualization and to strengthen the pico hydro system development. Field studies included end-user and artisan interviews, market research to determine availability of materials, site visits to establish lessons-learned from existing pico hydro turbine and small wind turbine installations, and collaboration with artisans to gauge capacity and working environments.

5.2 End-User Interviews

A data collection study in the M'muock village, was conducted in 2008 (Ehlers and Hertlein 2008). The village is separated into 27 districts and has a total estimated population of 7,000 residents. Twelve districts in the vicinity of potential wind turbine or pico hydro turbine sites were selected. Within these districts, approximately 1,150 households were randomly chosen for interviews. The questionnaires consisted of 17 questions for the owners and 24 questions for the women of each household. The data collection was carried out by local teachers that were trained in a workshop on the handling of the questionnaires (Ehlers and Hertlein 2008). During the 2011 research trip, informal interviews were held in M'muock and in other locations, with end-users regarding their experiences with pico hydro, specifically their views and interactions with the technology. Findings from the interviews and empirical observations were documented.

Within the 2008 interviews, an open question was posed regarding which particular problem was the primary concern for the individual. Electricity access was identified as the top response by more than a third of the respondents, followed by dwindling agricultural yields and health problems. Other problems mentioned included water shortage, problems in the storage of agricultural products, high education costs, less firewood, dirty water, poor roads, poverty, less acreage, high fuel and fertilizer prices, and lack of capital for investment (Ehlers and Hertlein 2008).

The highest overall household expenditure was for petrol (Fig. 5.1). Fifty-nine percent of respondents have access to vehicles (25 %), motorcycles (5 %) or gasoline generators (29 %). Other fuel energy costs are attributed to kerosene, which is generally used as lamp fuel for lighting, and firewood. Most residents harvest firewood from the surrounding forests (Ehlers and Hertlein 2008).

Considering lighting, 52 % of the population use open fires as their primary lighting, while 47 % use kerosene lamps. Use of electricity for lighting from gasoline generators or disposable batteries is only a tertiary alternative. During the study, 511 kerosene lamps were counted. The average usage was 10 h per day per lamp, relating to an average household consumption of approximately 3 L of kerosene, which would correspond to an average household spending of 5,000 XAF/month for kerosene lamp fuel (Ehlers and Hertlein 2008).

Petrol costs were 25 % higher for Ndungweh villagers compared to their urban counterparts, with quoted costs of 600 XAF/L in Dschang and 750 XAF/L in Ndungweh. The price for a gasoline powered generator was in the range of 30,000

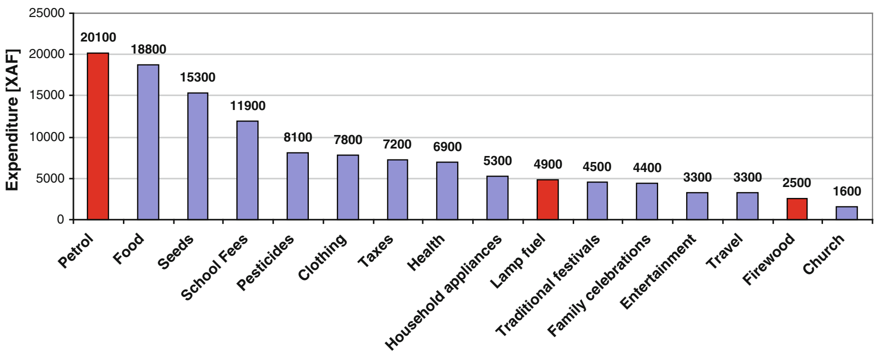

Fig. 5.1 Energy expenditure per household in M'muock (Adapted from Ehlers and Hertlein 2008)

XAF to 35,000XAF. Estimated petrol consumption was 5 L/day, resulting in a cost of 3,750 XAF/day. Diesel generators had a lower running cost of 3,000 XAF/day. Health clinics in the villages have diesel generators but a healthcare worker was quoted saying it was too expensive to operate. Kerosene costs were also higher for village residents with costs of 600 XAF/L in the village of Ndungweh and 450 XAF/L in Dschang. In the Ndungweh palace, kerosene lamps were used and observed to provide lower quality light than electric lighting while producing noticeable amounts of smoke.

Community applications include health centers and schools. One health center worker expressed the need for electricity for lighting, medical refrigeration and the use of microscopes. This was similar to the existing and intended uses of the electricity generated by the pico hydro turbine at the health center in Lewoh (details below). For the schools, an educator described the desire for electricity to provide students a place to study.

A commercially productive application was observed, where a gasoline engine was used in a bakery for dough kneading. In addition, a commercial coffee farmer expressed his desire for a coffee cracking machine. The existing coffee preparation procedure consisted of harvesting coffee cherries, sun drying and then transporting the shelled coffee beans to neighboring cities for cracking. It is to be noted that it was unclear if a manual or power-assisted coffee cracking machine was intended.

5.3 Market Research

Market research was conducted to establish general knowledge of material availability and costs based on approximate bill of materials formulated for pico hydro system conceptual designs.

It was found that materials useful for the turbine and generator such as steels, plastics, building construction material, motors, compressors, and automotive components were accessible within the peri-urban city of Buea. Electronic components for the controller were readily available in Bafoussam, the main city of the Western region. Obscure material sizes and specialized items were attainable from Cameroon's financial capital, Douala. The vendors of all of the components were generally microenterprises, with the exception of a few large building construction material distributors, such as Ste. Cogeni. A source of permanent magnets could not be found, which would be required if permanent magnet generators are to be employed for electrical production.

Table 5.1 Visited installation sites

Location	Application	Technology	Functioning?
Bafoussam	Hotel	Wind turbine	Yes
Bafou	Health clinic	Wind turbine	No
M'muock	Battery charging station	Wind turbine	Yes
Ndungweh	Palace	Firefly/Turgo	No/Yes
Ndungweh	Household	PMA Firefly	No
M'muock	Palace	Firefly	No
M'muock	Fon's residence	Firefly	No
Lewoh	Health clinic	Turgo	Yes

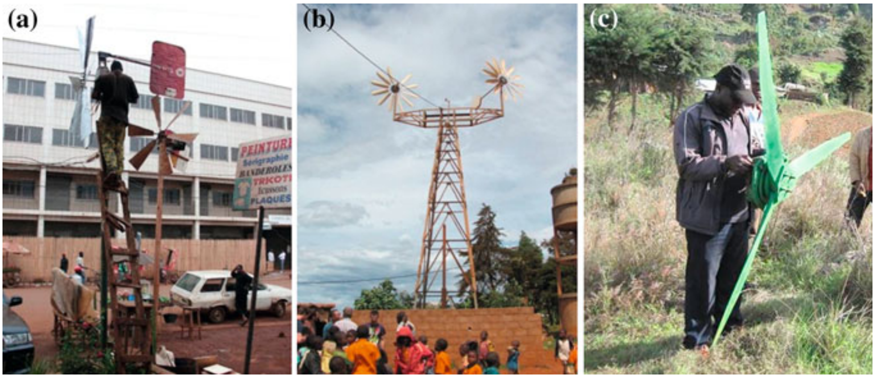

Fig. 5.2 Wind turbines (a) Bafoussam, (b) Bafou, (c) M'muock (Source: Ho-Yan 2011a)

5.4 Installation Site Visits

Several sites of pre-existing pico hydro and small wind turbine installations were visited in May 2011.Table 5.1 gives the sites visited, detailing the application and technology.

In Bafoussam, the third largest city in Cameroon, two small wind turbines were located on the street level outside of Hôtel du Centre (Fig. 5.2a). The turbines were designed and commissioned by the owner, a relatively affluent pharmacist with interests in wind turbines and renewable energy technology, and built by two employed metalworkers. The turbines consisted of six straight metal blades, transmission, permanent magnet generator and tail. The turbines were operational but inefficient. An electrician from Buea trained by GREEN STEP e.V. shared his knowledge and experiences with the pharmacist who was open to receiving the advice.

In Bafou, a foreign NGO donated approximately 50,000 Euros for the import and installation of a small wind turbine system for lighting and water pumping at a health clinic. The wind turbine system utilized two 12-bladed rotors, an electronic controller and a 24-unit battery bank (Fig. 5.2b). Local residents reported the costly and elaborate system functioned for approximately a year and has not been functioning since as early as 2008. The primary cause of the malfunction was unknown, but it was observed that a blade and tail of one of the turbines had disconnected, likely due to the high rotational speeds that would occur under no electrical load and high wind conditions. Health clinic personnel have attempted to repair the system, but they cannot access the required parts due to the lack of availability and high costs. They have contacted the foreign NGO to request further funding for the repair. During our visit, the health clinic and pump were connected to the electrical grid.

GREEN STEP e.V. installed a smaller wind turbine for battery charging in M'muock that has been in operation since 2008 (Fig. 5.2c). The wind turbine was locally built, based on the Hugh Piggot (2010) design. This design has been adopted by organizations in developed and developing countries including Nicaragua, Madagascar, and Mozambique. The design consists of three carved wooden blades mounted on a bearing and shaft assembly and connected to a permanent magnet generator constructed using epoxy, copper coils, and permanent magnets. This system has experienced failures, but unlike the system in Bafou, the system was promptly repaired. The day prior to the research team's arrival, high winds from a passing storm led to weld failure and the entire rotor and generator assembly disconnected and fell to the ground. Despite the fall, there was no damage to the rotor and generator assembly. The failed weld connection was a repeat failure and was repaired and further reinforced by a local welder to prevent future recurrence; electrical components were purchased from a local store to replace damaged connections. Both the welder and storeowner were not affiliated with GREEN STEP e.V. The turbine was fully functional by the following day. Had the research team not been present, a service person trained by GREEN STEP e.V. would have been sent to investigate and repair the fault. Previous failures were both mechanical and electrical in nature and addressed by GREEN STEP e.V. trained local personnel. Electrical related failures included ineffective dump loads in the battery charging circuitry resulting in the overcharging of batteries and also the improper use of batteries by end-users: the batteries were disconnected before being sufficiently charged. Both of these failure modes diminish the life of the batteries.

In 2008, four Firefly pico hydro turbines were locally manufactured and installed by GREEN STEP e.V. trained technicians in Ndungweh and M'muock, situated along water arteries near the users of power. None of the pico hydro systems operated longer than seven months (Urban 2011). The cause of failure was observed to be the wearing of brushes in the automotive alternators used as generators, which resulted in damage to batteries and inverters due to the lack of power. Once these issues were discovered, the users disconnected the pico hydro turbines and the systems rusted as they stood stagnant. Some of the systems were serviced and returned to use, but failed within the following two months (Urban 2011). Prior to the alternator failures, debris and siltation in the reservoirs caused blockages at the intake. This was addressed by capping the penstock, or intake pipe, using a steel can with punched holes in the end and porous netting to filter large debris from entering the penstock. Caretakers were instructed to clear the accumulated silt and debris regularly. During rainy seasons, water levels were very high and washed away portions of a penstock. Another failure occurred while maintenance was being conducted on a system. As the water flow through the turbine was shut off at the intake, the weight of the remaining water in the penstock created a vacuum as it exited out of the turbine, causing the penstock to implode. Locally improvised penstock modifications of cutting slits into a section of the penstock were implemented to avoid large vacuum formation during flow shutoff procedures. The slits would be blocked in succession allowing for a gradual decrease in flow rate through the penstock before complete flow shutoff.

There have been cases where caretakers often did not fulfill their responsibilities and GREEN STEP e.V. needed to proactively contact the caretakers for information regarding the well-being of the pico hydro systems. Caretaker training is an essential factor for the proper use and maintenance of pico hydro systems. Preferred methods are to have the village members primarily identify potential caretaker candidates and to then collaborate with the village for the final selection. The candidates were interviewed to evaluate intentions and capability to fulfill caretaker duties. Following the selection, the training was conducted on-site. This was practiced by another NGO for a 10 kW communal system in Quibeku, a village nearby Ndungweh. After the installation, the system was operational until a bearing failure occurred. This was independently identified by the village caretakers. The caretakers removed the faulty bearing and sent it out for repair.

To replace the inoperable GREEN STEP e.V. turbines at the Ndungweh palace, another NGO installed an imported Turgo pico hydro turbine system. It had been in operation for two months prior to the visit. It supplied electricity to the compound used for powering ten compact fluorescent light (CFL) bulbs and for charging mobile phones. Prior to this, light emitting diodes (LEDs) were used for lighting as it was seen to be the least energy intensive option, however, replacement LEDs were difficult to find within a reasonable proximity to the village and the LEDs were replaced with CFLs. Limited consultation occurred with the residents of the chief's palace as the wives of the chief (the chief was not present during our visit) did not have much information to offer regarding the turbine. This is a stark contrast to the process GREEN STEP e.V. had conducted prior to installation, where local craftspeople were invited to a training session. Only males participated in the workshop, however, one of the chief's wives assisted with the delivery of the training session and that led to her later successfully troubleshooting an issue involving a break in the penstock of the imported pico hydro turbine. As recalled from her prior training, she shut the valve to stop the water flow and repaired the penstock with rubber material and restarted the system.

The research team visited another imported Turgo pico hydro turbine installed by a Canadian NGO for a health center in the remote rural village of Lewoh intended for powering several fluorescent lights and a refrigerator for vaccine storage. The system consisted of an imported turbine with a 275 W to 520 W capacity permanent magnet generator, a sophisticated electronic controller, and a large battery bank. Prior to arrival, the lighting load had been wired to bypass the controller and was powered directly off of the turbine. This modification was performed by the health center doctor, whom had electrical training from college, because he noticed the electronic controller repeatedly shut off. The research team found that the main switch consistently turned off after 15 min in both no load and load conditions. The electrical fault was attributed to a malfunctioning potentiometer on a sub-circuit which shut off the main switch to safeguard the system and batteries from excessive draining in the event the turbine stopped operating. This issue was not easy to resolve without proper tooling, therefore the bypass circuit modification wired by the doctor was kept as is and the batteries were left disconnected from the controller to ensure safekeeping of the batteries and longer life. It was also observed that the 300 W to 480 W refrigerator was too large a load. The turbine's nominal output is 500 W but only achieved approximately 300 W at the time of the visit. This posed a challenge for the system and it was therefore advised to not use the refrigerator and to consider a smaller refrigerator if possible.

5.5 Work Environments

The vast majority of workshop facilities in Buea, Bafoussam, and M'muock ranged from permanent to semi-permanent open walled structures with compacted soil floor surfaces. Workshops were equipped with few tools. Tool inventory generally included an arc welder (most times home-made), vice, disc metal grinder and assortments of small hand tools (Fig. 5.3). The workshops were connected to the main electrical grid, which was observed to be a generally insufficient supply with varying voltages, not ideal for welding. The workshops were mainly

Fig. 5.3 Standard metal workshop (Ho-Yan 2011b)

Fig. 5.4 Pelton turbine cups (Ho-Yan 2011c)

unfurnished and improvised working surfaces were used such as discarded engine blocks or structural members. The metal workshop where the M'muock wind turbine was repaired was typical. Despite the constrained working conditions, adequate joint preparation practices were conducted and good quality welding was observed during the wind turbine repair.

There were two workshops that were the exceptions to that as described above. In Buea, there was a relatively large commercial workshop focused towards woodworking. It was equipped with automated tools including a planer, cut saw, table saw, belt sander, and band saw. The floor was a poured concrete pad and the workspace was furnished with worktables. In addition, metalworking was performed here as well. In Bafoussam, there was a metal workshop equipped with a lathe, commercially-made arc welder, punch, drill press, tooling for aluminum sand casting, metal grinders and custom tooling for jigs and patterns. Mills for palm oil processing were fabricated and have been a long-standing business for the craftsman. In addition, finished Pelton turbines were seen at the facility and the production quality was observed as very high. Several units had been made in the past and implemented in rural villages. Aluminum sand casting was used for producing Pelton cups for 10 kW and 15 kW systems. Pelton cups can be seen in Fig 5.4.

5.6 Build Trial

In Buea, a build trial of a propeller runner for a pico hydro turbine was conducted with a craftsman identified as the top participant from the GREEN STEP e.V. training. The craftsman had previous experience with wind turbines and another version of a pico hydro turbine. A hand-sketched schematic of a propeller runner concept design was provided three days prior to the trial to allow the craftsman to analyze the problem and develop independent solutions. It was explained that the unit was to be built with minimal guidance from the design engineer, if any. The schematic detailed a propeller runner with four circular arc curved blades with radial outward increasing chord length. Emphasis was placed on several aspects: the blade forming techniques, accuracy of the blade forming to the design specification, repeatability of the blade forming, assembly of the propeller. The trial was conducted in a rented workspace of a small metal workshop equipped with a commercial grade welder, disc grinder, assorted small hand tools and a stand-mounted vice. The workshop was owned by a welder who employed an apprentice. The craftsman typically rents workspace at a larger more equipped facility which was not accessible at the time of the trial. The craftsman was accompanied by two colleagues that were electricians by trade.

Materials were procured and consisted of mild steel pipe and thin mild steel sheet. The pipe was held in a vice and cut with a hacksaw to length. Straightness or level of cut was not checked. Material for the blades were measured and marked on the metal sheet. Blade blanks were cut using hand-shears. Due to the lack of tooling, a small I-beam was used as a makeshift mold to curve the blades (Fig. 5.5). The four blades were to be set equally apart in a circular array surrounding the circumference of the pipe. Spacing was accomplished by using a guide fabricated from a length of wire and then cut in four equal parts. When the blades were placed on the pipe, it was realized by the craftsmen that it did not sit flush on the pipe: modifications were made with a disc grinder in an attempt to achieve a closer fit (Fig. 5.6). Wire cutters were used to remove the burrs from the ground ends.

Welding of the blades to the hub was initially performed on the compacted soil floor, and then on a provisional stand (Fig. 5.7). Prior to the welding, care was not taken to clean the materials. The blades were initially tack welded for placement.

Fig. 5.5 Blade forming (Ho-Yan 2011d)

Fig. 5.6 Blade placement (Ho-Yan 2011e)

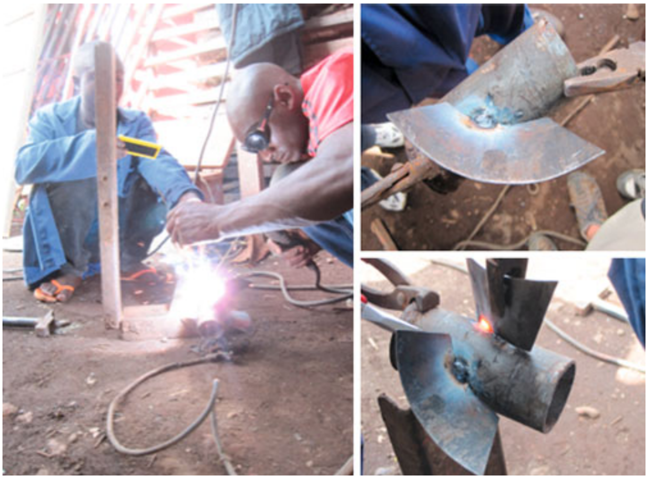

Fig. 5.7 Welding (Ho-Yan 2011f)

After welding, varying gap distances existed due to the insufficient grinding of the blade hub ends, forcing the master welder to apply additional filler material to the weld.

The build trial time duration was 3.5 h. The construction quality was poor. The blades were inaccurately formed and imprecisely repeated. The blades were misaligned on the hub (Fig. 5.8). The weld quality was also poor with incomplete penetration at some locations and burn-through in either the blade material or hub

Fig. 5.8 Final assembly (Ho-Yan 2011g)

(Fig. 5.8). The weldments were inconsistent in length, and discontinuous along the seams. Excessive porosity and weld splatter are seen on some portions of the welds.

5.7 Conclusions

The field research in Cameroon reaffirmed that access to electricity has been identified by the rural population in M'muock village as a priority. Currently there is great reliance on fossil fuels such as petrol, diesel, and kerosene; however, this can be substituted with renewable energy technologies to mitigate exposure to increasing fuel costs. Rural electrification, including pico hydro turbines, can provide social and economic benefit at the household, community, and commercial levels.

Most required materials for local fabrication of turbine systems were accessible in Cameroon, with general materials available in smaller cities, electronic components only available in larger cities and specialized materials only available in Cameroon's financial capital, Douala. Permanent magnets could not be found, which would be required if permanent magnet generators are to be employed.

Renewable energy systems, both imported and locally manufactured, have been implemented in Cameroon. Imported systems tended to be significantly more sophisticated. The imported pico hydro turbines in Ndungweh and Lewoh were operational and able to provide consistent power for lighting. However, this was overshadowed by the inaccessibility of technical support and replacements parts, with the impact more pronounced in the Bafou wind turbine installation. In addition, it is suspected that higher costs were incurred for these imported systems due to comparatively higher capital costs and import costs. The imported pico hydro systems should be monitored to determine the longevity of these systems and the actions taken in the event of a malfunction. The Ndungweh installation demonstrates potential for imported pico hydro systems when combined with the proper training of end-users. In contrast, the locally manufactured GREENSTEP e.V. models were not operational after several months of use, despite the maintenance and repair work that was performed. This highlights the importance for a more robust design.

Pico hydro is in its infancy stage however, interest does exist from both the consumer and technician perspective. The beneficiaries embraced the technology as seen in the actions taken to maintain and repair the systems. This was more prominent in cases where education and training were provided to the end-users and emphasizes the importance of knowledge transfer. An electrician spoke of his livelihood transforming since being trained and working as a small wind turbine and pico hydro system technician. He has become confident in his new craft, providing consulting and training services in addition to maintenance and construction. This was observed during an exchange with the pharmacist in Bafoussam as he provided technical advice. In addition, the artisan enrolled himself in a national artisan competition to display his self-built wind turbine. By establishing a knowledge base through training and learning-by-doing, improved efficiencies can be achieved to the system design and the manufacturing process. In addition, this may create work opportunities and empower artisans. Training must also extend to the end-users and caretakers of the systems as was evident in several pico hydro installations. Without trained individuals or end-users with prior experience or knowledge, which is often the case, systems remained inoperable after minor failures, additional damage often occurred and in some cases the investment was completely lost.

Results from a build trial demonstrated that a propeller turbine could also be built. However, the designs must be communicated in a clear manner within the Cameroon context and incorporate the working environment. The provision of additional artisan training, sufficient tooling and workspaces, will improve production quality and are essential to the success of these systems.

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Chapter 6
Ensuring Appropriateness of Biogas Sanitation Systems for Prisons: Analysis from Rwanda, Nepal and the Philippines

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Abstract Biogas sanitation systems are seen as a promising technology for institutional settings of developing countries as they combine effective treatment of human excreta and kitchen waste, while at the same time generating a renewable fuel source for cooking and a nutrient-rich fertilizer. The Water and Habitat Unit of the International Committee of the Red Cross (ICRC) has been involved in the realization of biogas systems in prisons for the last 10 years to improve the poor sanitary conditions in detention facilities. In partnership with local organizations, ICRC has replaced the undersized and deteriorating septic tank systems in prisons of Rwanda, Nepal and the Philippines with fixed-dome biogas systems. After at least one year of operation, the 13 implemented systems were assessed in terms of their technical performance, economic viability, environmental impacts and social acceptance. For this purpose, on-site investigations were conducted (observations, interviews, measurement of gas production and composition, and analysis of process stability, reduction of organic load and pathogen content). Eleven systems were in operation at the time of evaluation and displayed satisfactory process parameters with daily biogas production ranging between 26 L/person and 62 L/person (obtained in prisons where kitchen waste was added to the digester). The vast majority of detainees perceived the biogas systems positively, mainly because it provides a smoke-free source of cooking fuel that contributes to money saving, and because it improved the hygienic conditions in and around the prison.

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6.1 Introduction and Purpose

More than 2.5 billion people worldwide do not have access to basic sanitation (WHO and UNICEF 2012). The poorest and most vulnerable fraction of the world's population is mostly affected by this dramatic situation, which severely threatens health wellbeing and livelihoods. Prisoners are among the most discriminated groups, often suffering from detrimental sanitary conditions. The International Committee of the Red Cross (ICRC) visits people deprived of freedom in numerous countries and assists prison authorities in their efforts to improve conditions of detention among which sanitation is one element. Within this scope of activities, the Water and Habitat Unit of ICRC has been involved in the realization of biogas systems in prisons of Rwanda, Nepal and the Philippines for the past ten years. Such biogas projects have been realized in partnership with local expertise and technical institutes, such as Kigali Institute of Science and Technology (KIST) and EREP SA for the case of Rwanda (2009), Biogas Sector Partnership Nepal (BSP-N) for Nepal (2009), and Practical Action Consulting for the Philippines (2011). Main reason for this intervention was to substitute the undersized and deteriorating septic tanks with biogas systems and hereby improve the sanitary conditions, reduce the health risks of the detainees and provide a renewable and smoke-free source of cooking fuel.

This paper aims at identifying the key questions to address so that biogas systems are appropriate technologies for the prison context of developing countries from a sustainable development perspective. It relies on results from different field studies conducted by ICRC and partner organization, which assessed the technical performance, economic viability, environmental impacts and social acceptance of the implemented systems after at least one year of operation. Key lessons, best practices and recommendations in terms of performance, impacts and acceptance of the biogas systems are highlighted.

6.2 Design and Methods

The main findings are derived from three studies conducted between 2009 and 2011 (Devkota 2011; Lohri 2009; Mottet 2009), which involved on-field investigations on 13 biogas systems in 11 prisons of Rwanda (Muhanga, Gikongoro, Cyangugu), Nepal (Kaski, Chitwan, Kanchanpur) and the Philippines (Cagayan de Oro, Davao, Sultan Kuradat, Manila, Cradle). The results are synthetized by using a conceptual framework that groups the various issues according to the different sustainability aspects: Technical, operation and maintenance, economic, environmental and socio-cultural aspects. The methods used to assess these various issues are:

- Observations of the state of the biogas systems (functionality of complete system including inlet, digester, gas utilization devices, outlet) and operational procedures (handling and use of waste, water, gas and effluent, hygiene, and allocation of responsibilities).

- On-site measurements such as:
  - Daily gas production and biogas composition such as Methane (CH_4), Carbon Dioxide (CO_2) and rest gases;
  - Analysis of process stability and physico–chemical characterization of in- and outflow: pH, temperature, Redox potential, electrical conductivity, Chemical Oxygen Demand (COD), Ammonium–nitrogen (NH_4–N), Phosphorus (P);
  - Measurement of pathogen contamination of digested effluent (*E.coli* as indicator).
- Sampling and laboratory analysis of Total Solids/Total Suspended Solids (TS/TSS), Volatile Solids (VS) and helminth egg count.
- Semi-structured interviews with a wide range of stakeholders at each prison site (prison staff, detainees, surrounding population, authorities, ICRC Water and Habitat staff) to find out:
  - Acceptance and perceived impacts (including benefits and burdens) of the biogas systems in comparison with previous septic tank systems;
  - Investment, operational and maintenance costs;
  - Fuel or wood savings by using biogas for cooking.

6.3 Results and Discussion

6.3.1 Technical Aspects

6.3.1.1 General

Table 6.1 provides an overview of all 13 biogas systems studied. Results show that the anaerobic digestion (AD) systems in operation all have satisfactory process stability, i.e., favorable conditions for AD are prevailing: The range of pH (7.1–8.4), digester temperature (mesophilic range 22.2–36 °C) and negative Redox potential all indicate a suitable environment for AD. The comparison of the hydraulic retention time (HRT) needs to be interpreted with caution as calculations were not done in a coherent way. In Rwanda the total digester volume was used for the calculation (a) while, in Nepal only the active slurry volume in the digester was considered (b) and in the Philippines the combined volume of digester and compensation chamber (c) was used for calculation. Considering this, the HRT results of the Philippines are strikingly low, which means either that the daily inserted waste quantity (including flush water) is much higher than planned or that the plant is simply under-dimensioned. Such low HRT results in a low hygenization and methanization rate of organic matter and should thus be avoided.

Table 6.1 Overview of evaluated biogas sanitation systems in prisons (types, sizes, basic indicators for process stability)

	Location	Start of oper-ation	Operationality	Number of detainees	Persons connected to biogas toilets	Type	Digester size (m^3)	pH	Temp (°C)	Redox Pot. (mV)	HRT (days)
RW[a]	Muhanga	2005	Yes	7604	n/a	Serial UG[d] domes	500 (5*100)	8.1	22.2	- 41	n/a
	Gikongoro	2007	Yes	3385	2600	Serial UG domes	300 (3*100)	7.9	24.6	- 42	38
	Cyangugu	2002	Yes	3499	2500	Serial UG domes	400 (4*100)	8.4	22.5	- 64	49
NP[b]	Kaski	2008	Yes	65	65	UG dome	10	7.2	26.4	- 372	23.1
		2008	Yes	135	135	UG dome	12	7.1	25.6	- 401	20.4
	Chitwan	2008	Yes	115	115	UG dome	10	7.1	29.8	- 389	13.3
		2008	Yes	155	155	UG dome	35	7.4	28.8	- 391	31.6
	Kanchanpur	2008	Yes	106	106	UG dome	10	7.2	30	- 402	14.5
PH[c]	Cagayan de Oro	2009	Yes	1112	800	Tunnel	25	7-8	36	- 100	14.6
	Davao	2008	Yes	1142	369	Tunnel	10	7.5	35.5	- 64	12.7
	Sultan Kuradat	2009	Yes	270	360	Tunnel	10	7-8	36.5	- 80	17.4
	Manila	2007	No	519	519	AG[e] dome	24	n/a	n/a	n/a	22.8
	Cradle	2008	No	220	240	Tunnel	12	n/a	n/a	n/a	22.4

[a] *RW* Rwanda; [b] *NP* Nepal; [c] *PH* Philippines; [d] *UG* underground; [e] *AG* above ground

6.3.1.2 Inputs

The studies revealed that the total amount of human waste input from sanitation facilities in the prisons can be anticipated in the range of 3.3–4.9 L/person/day (human feces per adult person and day between 0.25 and 0.4 kg and between 1 and 1.5 L of urine per person plus 2–3 L/person/day water used for anal cleansing and flushing). This is the amount per person that flows into the biogas reactor. Generally, it is advised to ensure that the digester is fed regularly with a homogeneous substrate input in terms of quantity and quality. Changes in quantities can hardly be prevented (see Sect. 6.3.1.3 for technical solutions to adapt to changes in input quantity). Due to the uniformity of daily diet observed in all prisons, relevant changes in excreta quality are not likely to occur. Kitchen waste (such as vegetable and fruit peelings, residuals in cooking pots, food leftovers) is a highly suitable additional feedstock and leads to considerable increase of biogas production (discussed in Sects. 6.3.1.4 and 6.3.3).

6.3.1.3 AD Technology, Design and Site Selection

External heating of the digester is hardly ever an option due to an unfavorable institutional setting as well as an unfavorable energy balance and associated financial issues. Suitable average local temperature is thus crucial and should not go below 15 °C, as this would slow down microbial activity too much. When deciding about the site for the digester, the criteria should include suitable ground conditions for construction work, possibly an unshaded location as close as possible to the toilets and kitchen to minimize pipe lengths. In addition, the site needs to be inspected beforehand during rainy season to identify potential areas of stagnant water and to ensure sufficient gradient to enable discharge of the effluent by gravity. Fixed dome underground digesters which have been adapted to local circumstances, (e.g., the stone or brick masonry model GGC2047 for Nepal, see Fig. 6.1) are considered to be most suitable for the prison context in developing countries as the technology is well known and widespread, cost-effective, and the required components locally available. Depending on the availability of materials, digester walls can either be built with bricks, stones or concrete hollow blocks

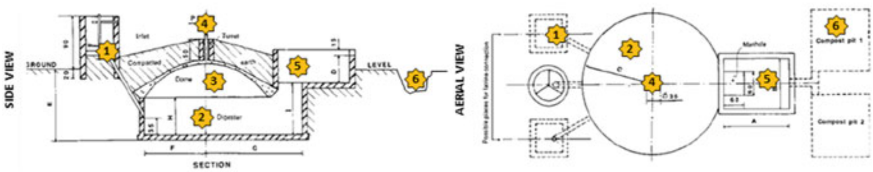

Fig. 6.1 Side view and aerial view of typical fixed dome underground digester (GGC2047); *1*: Inlet chamber with inlet pipe, *2*: Digester, *3*: Dome (gas storage), *4*: Gas outlet, *5*: Compensation chamber with overflow point, *6*: Storage/compost pit

instead of using concrete. Figure 6.1 presents a schematic overview of a fixed dome underground digester with its relevant components.

Major technical problems of the evaluated systems included insufficient slope (less than 5 %) of the inlet pipe which led to frequent blockage (Chitwan 10 m^3, Chitwan 35 m^3) or which made operation impossible (Manila 24 m^3). Absence of downward gradient between compensation chamber and storage pits resulted in a backflow of rainwater into the digester, thereby diluting the active slurry content (Kaski 10 m^3). Lack of water condensation traps (all systems in the Philippines) also leads to blockage of gas pipes. The reasons of failure in the biogas reactor called Cradle (12 m^3) was attributed to irregular feeding, and lack of operation and maintenance. Underlying causes for this is the lack of a proper transfer of technical knowledge and skills during the change of personnel responsible for operation. Furthermore, the reluctance of specific personnel to take charge in the operation was mentioned as additional reason for failure.

A rule of thumb for digester volume calculation is 100 L of digester volume required per person, (e.g., a prison with 200 detainees needs a 20 m^3 digester). This is based on the estimation that 3.3 L/person of diluted substrate (feces, urine, flush water) is added and a HRT of 30 days is envisaged. The design of fixed dome underground digesters normally considers gas storage volume to be 25–30 % of the total digester volume and the volume of the compensation chambers between 55 and 60 % of the dome volume. Digesters should not exceed a total volume of 100 m^3 else static reasons demand expensive structural reinforcements.

Construction of multiple digesters in series as observed in Rwanda (Fig. 6.2) is preferable to one single larger digester. On one hand, it facilitates maintenance work (e.g., internal re-coating with acrylic emulsion paint) as the digester under repair can be by-passed); on the other hand it is considered as an appropriate method to compensate for fluctuation in number of detainees (and the corresponding change in substrate quantity). The total volume of the digesters built in series needs to be appropriate for treatment of all the waste when the prison is occupied to its maximum. If the number in detainees declines, this does not affect

Fig. 6.2 100 m^3 digesters in series (Rwanda; Reprinted here with kind permission EREP 2004)

Fig. 6.3 Internal baffle wall (Reprinted here with kind permission KfW 2009)

the performance as the HRT increases, leading to better degradation of organic material and better hygenization of the feedstock.

For prisons with a single digester (capacity of 500 detainees and less), the inclusion of an internal baffle wall in the digester (Fig. 6.3) or the 'non-straight' line layout of digester and compensation chamber is an option to increase the Solid Retention Time (SRT) without increasing the size of the digester (thus not increasing construction costs). Gas tightness of the dome is imperative and can be ensured by applying layers of acrylic emulsion paint. No concluding statements can be given regarding lifespan of the system as all evaluated biogas plants were relatively new: Literature findings (KfW 2009) indicate a digester lifespan of 20 years, piping lifetime of seven years and the renewal of acrylic emulsion paint inside the dome every 4–6 years.

It is advantageous to use a standardized design (digester models, diameter of pipes) for all biogas systems in one country as it simplifies knowledge transfer, provision of training and uniformity of spare parts needed. Reinforcement rods constitute a considerable element of expenditure, thus should only be installed where necessary (slabs of compensation chambers, possibly in large domes, but not in walls, inlet and outlet chambers). The outlet gas pipe needs to be properly fixed in a turret. In colder climates, sufficient soil backfilling on top of the digester is important (e.g., recommended minimal depth underground on top of the reactor in Nepal is 40 cm) not only to ensure protection of the dome, but also to reach adequate counter-pressure and to minimize the temperature change between seasons and day/night, which is preferred for consistent microbial activity. In year-round warm climates (e.g., in the Philippines) a dome that is exposed to sunlight is considered beneficial as it helps increase the temperature of the digester, thus promoting gas production.

The gas pipes need to be installed as direct as possible, avoiding unnecessary elbows as this leads to reduction of gas pressure. It is absolutely essential to install condensation traps at the lowest points of the gas pipe. Vapor, a natural component of biogas, condenses in the pipe and eventually leads to blockage of the pipeline so that the gas does not reach the kitchen anymore. Regular emptying of these water traps is crucial (see Sect. 6.3.2.1).

Regarding biogas stoves, the following points need to be taken into account: The approximate average biogas consumption rate per (household-sized) stove is 400 L/h. If liquefied petroleum gas (LPG) stoves are used, modifications are required to ensure proper burning. For this purpose, the nozzle hole needs to be enlarged to 3 mm diameter as methane has larger particles than LPG, explaining the need for a larger opening to attain the needed volume flow. The burner holes need to be enlarged to 4 mm diameter. The air intake ports needs to be provided with a regulating flap behind the nozzle to balance the needed volume for proper burning of the gas.

As hydrogen sulphide (H_2S), a natural component of biogas, is extremely reactive with most metals, kitchen equipment such as stoves and stovepipes are prone to corrosion. It is therefore advised by some experts to install a H_2S trap (Mottet 2009): Two columns (one for desulphurization, one for regeneration) filled with iron oxide for absorption of H_2S; the H_2S reacts with the iron oxide to form iron sulphide and water. Addition of sufficient air converts the iron sulphide back to the oxide and leads to precipitation of elemental sulphur.

6.3.1.4 Outputs

The reduction of COD serves as an indication of the digester performance and can be calculated by comparing the COD of the input with that of the effluent. The larger the reduction, the more organic matter have been degraded and transformed into biogas. With the exemption of the Davao system, where most likely a mistake in sampling or analysis occurred, the COD reduction in all reactors in Nepal and the Philippines show very satisfactory ranges between 89.6 and 98.4 %. The study in Rwanda compared the COD content of the effluent after digestion to the same effluent after post-treatment in the septic tanks.

The daily gas production per person was measured in the prisons of Nepal and partly in Rwanda. It ranges from 25.9 L/person/day (Chitwan 10 m^3) to 61.9 L/person/day (Kaski 20 m^3) (see Fig. 6.4). The large variations can be explained by the fact that in some reactors kitchen waste was also added, which considerably increases the gas yield. The measurements of the methane (CH_4) fraction in biogas presented in Fig. 6.5 reveals results between 57 % (Kaski 20 m^3) and 78 %

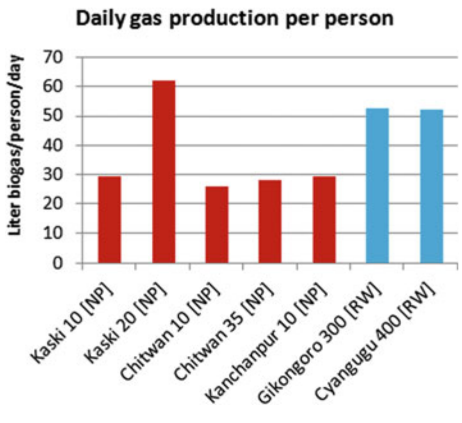

Fig. 6.4 Comparison of daily biogas production per person

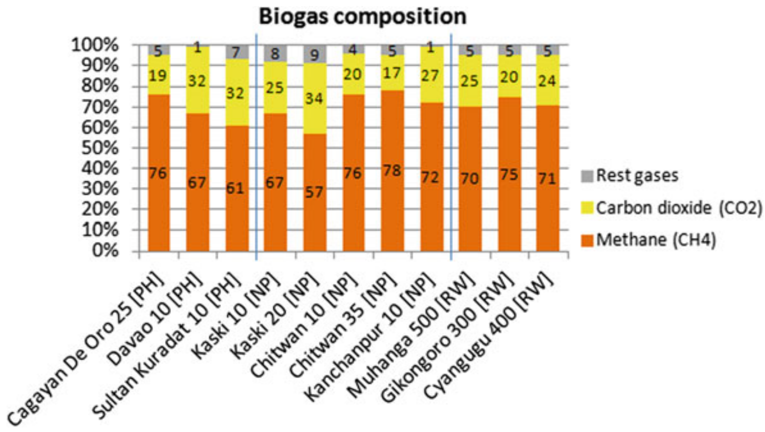

Fig. 6.5 Comparison of biogas composition in AD systems of Philippines [PH], Nepal [NP] and Rwanda [RW]

(Chitwan 35 m^3). The low CH_4 content in Kaski can also be explained by kitchen waste feedstock (rich in carbohydrates), which substantially increases the gas production while at the same time lowering the methane content, as kitchen waste releases high quantities of CO_2. The average CH_4 content in all evaluated operational systems is 70 %.

The World Health Organization (WHO) lists two indicator organisms for safe agricultural use of greywater, excreta and fecal sludge (WHO 2006): *E.Coli* and helminth eggs. The quality of the effluent directly after the anaerobic digestion process was found not to be acceptable for restricted irrigation (crops that are not eaten raw) as particularly helminth eggs were not eliminated during the anaerobic digestion process. An adequate form of post-treatment is therefore required. Apart from using the old septic tanks for settlement of solids and therefore partial elimination of pathogens, the reports advise an additional composting step (mix of effluent with fresh agricultural waste) or a soak-pit/drying bed (as practiced in Rwanda) as pathogens normally cannot survive in a dry environment. However, as helminth eggs are very resistant, this method first needs to be tested, properly analyzed and proven. In any case, it has to be emphasized to only apply the effluent to products that are not eaten raw or need peeling (e.g., banana).

On this aspect, the biogas systems in Rwanda are considered as example of best practice and, if space availability does not constitute a problem, can be seen as a model for replication. First of all, the digester installation in series leads to a higher HRT with a consequential higher reduction of pathogens (HRT 30–40 days; 0.5 log units). The digested effluent is further directed into the previously used septic tanks where sedimentation of remaining organic matter, helminth eggs and parasites takes place (SRT 15 years; maximum pathogen reduction). From there, the post-treated effluent flows in mud canals to a soak-away pit where liquid infiltrates into the soil (HRT some days, weak pathogen reduction) and the remaining

Fig. 6.6 Post-treatment in Rwanda: Septic tanks; canal for post-treated effluent; soak-away pits and dried residuals; entrenched manure in banana field; use of manure for pepper breeding (*left* to *right*; reprinted here with kind permission Mottet 2009)

organic matter accumulates, dries out and can finally be used as organic fertilizer. In Rwandese prisons, the organic manure is entrenched between banana trees or added as fertilizing mix to pepper seedlings (Fig. 6.6).

It is important to note that the digested effluent needs to be diluted with water before application on the plants to reduce the osmotic pressure (high salt content measured as electrical conductivity), and to dilute the high nitrogen content. This Rwandese method of post-treatment in septic tanks not only results in additional reduction of pathogens, but also to further COD reduction between 55 and 89 % compared to the digested effluent.

Another option is to mix the digested effluent with raw material (e.g., agricultural waste) in covered compost pits. In the resulting exothermic aerobic digestion process, high temperatures (70 °C) are generated that lead to elimination of remaining pathogens. However, this option requires more regular working efforts (turning of compost) as it has to be ensured that sufficient oxygen reaches the organic matter to be composted.

6.3.2 Operation and Maintenance

6.3.2.1 Stakeholders' Responsibilities

Prior to the construction of a biogas system, a set of relevant points need to be discussed and agreed upon with the prison authority and the detainees. By means of user trainings/workshops, the detainees have to be informed about the biogas system, including:

- Water for anal cleansing and flushing toilets: Regulation of maximum quantity of water used per flush (3 L).
- Use of detergents: No chlorinated substances but only easily biodegradable detergents should be used for toilet cleaning to avoid inhibition of the anaerobic digestion process. If chlorinated products must be used for the general disinfection of the toilet area (floors, walls, etc.), in case of epidemics for example, it

should be avoided that the cleaning liquids enter the toilet opening and reach the AD to avoid inhibition of the anaerobic digestion process.

- Management of greywater: Greywater from washing hands, food, clothes and dishware as well as from showering is not a suitable feedstock for AD systems as it is highly diluted, i.e., low organic content leads only to minimal increase of biogas generation while requiring a large digester size to ensure sufficient HRT.
- Kitchen waste: Importance of adding kitchen waste to the digester (to increase gas production and to meet design requirements). Be aware of existing kitchen waste handling and 'competitors' (e.g., pig farmers in the vicinity who pick up kitchen waste and possibly pay for it).
- Particle size of kitchen waste: The size of particles needs to be reduced (as a general rule: pieces of max 5 cm, but this has to be seen in correspondence to diameter of inlet pipe) before feeding kitchen waste into the digester in order to prevent blockage and to facilitate microbial biodegradation.
- Blockages: Counter-measures in case of blockages (mixing with water, stirring, de-blocking with long tube).
- Gas consumption: Necessity of total gas consumption produced every day to prevent overpressure with consequential methane slips through compensation chamber (greenhouse gas emission) or slurry overflow.
- Expectations: It is important that the prison authorities and detainees have realistic ideas about what can be expected from the biogas system (it needs to be explained that biogas will only substitute a certain amount of previously used cooking fuel and the amount can be influenced by following the agreements such as kitchen waste feeding, minimized water flushing, etc.). Additional changes/benefits will be a reduction in cooking time (e.g., 25–33 % in Rwanda) compared to use of fire wood, less pot cleaning due to less soot, and absence of smoke.
- Biogas flame: Adjustment of nozzle and burner holes, regular cleaning of stoves is required.
- User committee for O&M: A user committee needs to be appointed which is responsible for smooth operation (e.g., ensuring that all gas is consumed by using it between meal-preparing times for water cooking, bread baking or simply burning it) and maintenance (the reasons behind regular check-ups need to be explained, e.g., that gas leakages in the kitchen threatens the health of kitchen staff; instructions for basic repair work).
- Maintenance tool kit: A set of spare parts with tools has to be provided. It has to be pointed out that even relatively small problems (e.g., forgotten condensed water drainage, leakage of biogas in kitchen or blockage of inlet pipe) can lead to adverse consequences such as risk to human health (biogas leakage in kitchen), overflowing toilets with cumbersome repair work or even to a system standstill (blockage of inlet pipe).
- Incentives: The incentives (money, better conditions, kind) of the persons with assigned tasks (e.g., kitchen waste feeding, emptying of water traps, cleaning of stoves, leakage checks, etc.) needs to be jointly negotiated and a controlling

body has to be appointed which is responsible to check if tasks have been properly conducted.
- Continuity of AD knowledge and skill: It is crucial that the number of members in the O&M group remains constant. This will prevent loss of knowledge and skills when AD-competent detainees are released.
- Transfer of well-informed and influential personnel: The frequent transfer of jail personnel also implies a risk that relevant knowledge is lost. Often even more critical is the departure of the 'head of detainees' (the person within the detention area with most influence). It was observed that the functionality of the AD system often correlated with the personal motivation and involvement of this person. In case of succession, significant attention needs to be dedicated to transfer the required knowledge and organizational understanding to ensure continued smooth AD operation.
- Effluent handling: The associated risks with effluent handling needs to be mentioned and methods shown to minimize health hazards. Protection clothes such as rubber gloves and boots should be worn and persons with open wounds should not be allowed to handle effluent. Directives need to be given that thorough hand washing with soap is required after every activity involving effluent contact.
- Application of effluent/digestate: Proper application of digestate needs training (e.g., post-composting, entrenchment of manure, dilution of effluent).

6.3.2.2 Health Risks and Mitigation Measures

If a biogas system is properly designed, constructed, operated and maintained, the risks to human health can be kept within reasonable limits.

Although from a technical and economic point of view, reduced flushing water inflow is desirable (higher HRT, smaller dimensioning of digester, i.e., lower costs), it needs to be in balance with the demand for sound hygiene. A compromise has to be found to avoid excessive water use and to still keep up the level of hygiene required to avoid transmission of diseases.

The compensation chambers need to be covered with reinforced slabs (detainees were reported to have fallen inside the chambers (EREP 2004). Furthermore, gas leakage has to be avoided, especially in areas of human activity (e.g., kitchen). To minimize the risk of leaks, exposed gas pipes (prone to stumble over) need to be properly covered and vulnerable plastic pipes in the kitchen (connected to the stoves) should be protected from mechanical and thermal damages. As H_2S is a highly toxic and flammable gas that is heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. However, due to its smell (similar to rotten eggs), it helps to detect leakages (methane and carbon dioxide are both odorless). Still, if the kitchen environment cannot be properly ventilated, the installation of a H_2S-trap as recommended by Mottet (2009) is advisable. Another safety device recommended is the installation of a simple gravel filter in the gas pipe to prevent back-flow of the flame (EREP 2004). There is a theoretical risk of explosion if 6–12 % of CH_4 is mixed with air (Deublein and Steinhauser 2011). The knowledge of the detainees regarding AD and in particular the potential misuse of biogas as explosive device is considered a minor risk.

When manually desludging the digester, a prior ventilation of the digester is indispensable to avoid exposure to toxic gases and suffocation. In addition, as a result of the explosion issue mentioned above, open fire or smoking has to be prohibited when working in the digester. As mentioned above (Sect. 6.3.2.1), special attention needs to be dedicated to any handling of effluent.

6.3.3 Economic Aspects

In Rwanda and Nepal, the overhead of the implementing biogas company amounted to 50 % of the total costs (i.e., material and labor account for 50 % of the total costs, whereas the other 50 % was charged by the company for their planning and supervision work). The average cost of a biogas system per cubic meter was found to be 230 US$ in the Philippines, 250 US$ in Nepal and 300 US$ in Rwanda. It has to be noted that the evaluations in Rwanda and Nepal used the total digester volumes for this calculation, while the Philippines-report based the cost/m^3 on the total system volume (digester + compensation chamber).

Based on the country reports, the savings from substitution of cooking fuel are as follows: In Rwanda, the savings resulting from reduced consumption of fire wood amount to 26–53 US$/day. For Muhanga, a reduction of money spending was reported to be 40 %. The financial savings in Nepal amount to 17 % (Chitwan), 22 % (Kanchanpur) and 41 % (Kaski due to kitchen waste addition) compared to the time before using the biogas system. In the evaluation of the Philippines, monthly savings of 5 % is reported (Cagayan de Oro prison). Future operational costs need to be envisaged for replacement of damaged parts, repairing and desludging (every 5–10 years, EREP 2004), but budget for it is context-dependent. Approximate payback periods were only calculated in Nepal. The results of the calculations, which did not consider price fluctuations and eventual costs of repairing and digester desludging, were 1.5 years (Kaski), 5.4 years (Chitwan) and 3.7 years (Kanchanpur).

6.3.4 Environmental Aspects

As mentioned above, a substantial amount of firewood is saved by using biogas, leading to reduced deforestation in the vicinity of the prisons.

Table 6.2 presents the results taken from the evaluation reports, emphasizing the total annual saving of firewood per prison.

Table 6.2 Overview of firewood savings per prison

	Location	Digester size (m^3)	No. of detainees	Total firewood saving (tons/year)
RW[a]	Muhanga	500 (5*100)	7604	3.50
	Gikongoro	300 (3*100)	3385	1.75
	Cyangugu	400 (4*100)	3499	1.1–2.1
NP[b]	Kaski	10	65	3800 L kerosene*
	Kaski	12	135	
	Chitwan	10	115	10
	Chitwan	35	155	
	Kanchanpur	10	106	4
PH[c]	Cagayan de Oro	25	1112	18.25
	Davao	10	1142	13.14
	Sultan Kuradat	10	270	9.13
	Manila	24	519	n/a
	Cradle	12	220	n/a

RW[a] Rwanda; *NP*[b] Nepal; *PH*[c] Philippines *Equivalent to 8.5 t of fire wood (Kerosene: 46 MJ/kg; 3800 L = 3040 kg kerosene [1 kg = 1.25 L]) = 139'840 MJ = 8.48 t of wood [16.5 MJ/kg])

Large differences between the countries were found which can to some extent be explained: Some of the detention facilities used improved cooking stoves but others use conventional method of cooking with open stoves, which explains the large consumption of wood. Furthermore, in the Philippines, hard wood such as pine, oak, beech hardly exists. For cooking purposes, almost exclusively lightwood is used with a lower heating value and often the wood is still moist. If (imported) hardwood is available, this expensive and exclusive wood type is predominately used for construction of buildings. Although the absolute number of firewood savings in Rwanda is small compared to the other prisons, the reduction of firewood consumption is reported to be between 25 and 40 % in reference to wood volume.

6.3.5 Socio-Cultural Aspects

The biogas systems are nowadays, after an initial phase of slight hesitation, favorably perceived by the vast majority of detainees. The initial fears included risk of disease transmission and bad taste of food that was prepared with biogas (as it is generated from human waste). However, as no negative effects were observed, these concerns gradually faded away. The main advantages in comparison with the previous (septic tank) system were mentioned to be the improved hygiene in the toilets combined with the absence of overflowing toilets and especially the generated energy. The reports also state a change of perception of the detainees: from excreta that was seen as waste, towards considering it as a valuable resource of energy. It was observed that the biogas systems are perceived as energy systems rather than as sanitary treatment systems.

Nighty-eight percent (98 %) of the interviewed detainees in Nepal and 100 % in Rwanda reported that the living conditions have improved since the installation of the biogas system (the report from the Philippines lacks this information). The following underlining arguments were given:

- Less smoke in the kitchen;
- Improved sanitation and hygiene (also less insects);
- Cleaner environment (jail in general and kitchen);
- Time saving through cooking with biogas;
- Money saving (substitution of expenses for previous cooking fuel);
- Assurance of being able to cook and eat (no more shortages of cooking fuel, i.e., firewood);
- Fewer outbreaks of diseases.

In some prisons where neighbors had previously complained about the odor and the overflowing feces, jail staff nowadays face much fewer complaints from the neighborhood.

6.4 Conclusions

As a technology is only as appropriate and good as its design, acceptance, operation and maintenance, these points deserve the main attention of any performance evaluation. The evaluation conducted in Rwanda, Nepal and the Philippines showed that satisfactory operation of a biogas system can be achieved if adequate attention is given to the site selection, dimensioning and managerial aspects of the system. For this, it is crucial to understand the local climatic and geotechnical conditions, sanitary habits, waste flows and power relations in the prisons. It is particularly important to ensure support and active involvement of the head of detainee as he/she has the privilege to allow and command the detainees to leave the prison walls for regular maintenance work. Kitchen waste addition can boost (even double) the biogas production, but its use might be in conflict with potential competitors (e.g., local farmers who use it as animal feed). To deal with high fluctuation in detainee numbers, it is advised to install digesters in series instead of a single large one. This ensures sufficient HRT satisfactory reduction of organic matter, increased pathogen reduction and at the same time enhances biogas capture. This paper listed relevant points that have to be discussed with detainees and prison authorities prior to the digester installation. It is absolutely essential to give proper training for the users in order for them to get an understanding of the requirements of a well-functioning system. In addition, a maintenance strategy needs to be in place that includes clear allocation of responsibilities, a task schedule and control mechanisms to check if duties have been conducted properly. Biogas systems are favorably perceived by the vast majority of the detainees as they have led to improved living conditions and reveal more benefits compared to the previously installed septic tanks. Rather than being regarded as sanitation system, the biogas technology is considered as an energy system. However, while a biogas system can be an appropriate treatment technology for blackwater (feces, urine, flush water) and kitchen waste, it does not present a suitable solution for treatment of the highly diluted greywater (shower water, kitchen water).

Overall, experiences in Rwanda, Nepal and the Philippines revealed that the systems could run successfully and thereby improve the conditions of detention if the discussed set of relevant issues is considered right from the beginning. Key for this is the availability of AD knowledge, skills and experiences of the constructing company and the involvement of detainees at every stage. It has to be ensured that the AD knowledge is kept within the prison walls despite frequent turnover of people (detainees and prisons' staff) in charge of the system. The evaluations form an essential and integral part of assessing the appropriateness of the biogas systems, as they provide a reality-check, help to make weaknesses apparent and lead to adaptations of the system according to local needs and capacities.

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Chapter 7
Technologies for Smallholder Irrigation Appropriate for Whom: Promoters or Beneficiaries?

R. P. S. Malik, C. de Fraiture and Dhananjay Ray

Abstract Fifteen years after the successful introduction of treadle pumps for small farm irrigation in the North Bengal region of India, the socio-economic and technological landscape has changed dramatically. However, donors have continued to support treadle pump programs. Revisiting the factors that contributed to its initial success, the authors in this paper examine whether the use of treadle pumps continues to be an appropriate technology for smallholder irrigation. The results suggest that treadle pumps, when introduced during the mid-1990s, were successful because of a near technological vacuum at that time. Over the years, with the advent of small affordable diesel engines, motorized pumps have become widely available and a large rental market for water and pumping equipment has emerged. The farmers started abandoning the treadle pumps. Growing labor scarcity, rising labor wages, and increasing concerns over drudgery also dissuaded farmers from using the labor-intensive treadle pumps. The study reaffirms that the adoption of a technology is a dynamic process and that a technology that was appropriate at one point in time will not necessarily remain so at other times. It underlines the need for regularly revisiting technology choices and independent monitoring to understand better the changing landscapes of smallholder irrigation. This will ensure that the technologies desired most by beneficiaries—not just by promoters—get the support and promotional backing of the donors and governments for effective poverty reduction.

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7.1 Introduction and Purpose

The treadle pump is an elegant, foot operated water lifting device which, by using suction force, lifts water from rivers, swamps, reservoirs, and shallow wells (hand dug) over a depth ranging from 0 to 8 m to the ground surface where it is intended to be used by farmers for irrigation, livestock, domestic, and other purposes. Invented by Gunnar Barnes in the 1970s, the treadle pump was first introduced in Bangladesh by the non-governmental organization (NGO) Rangpur—Dinajpur Rural Service (Orr et al. 1991). Treadle pumps appeared to be an ideal technology for smallholders at the time because they were cheap, running costs were close to zero, pumps could be manufactured and repaired locally, and they could be easily transported between fragmented landholdings. Using body weight and leg muscles to push down the treadles, they were also less tiring than other manual water lifting devices available using arm muscles (Chancellor and O'Neill 2000; Lambert and Faulkner 1991; DTU 1991). The manufacturing price of US$ 15 for the simplest treadle pump model made of bamboo compared very favorably to the nearest alternative manual pump available in Bangladesh in the 1980s. The alternative irrigation technology, a heavy 5 Horse Power (HP) diesel pump costing around US$ 500 in 1990, was largely out of reach for all but the richest smallholders (Polak and Yoder 2006). These factors contributed to successful marketing and uptake of treadle pumps by the smallholder farmers in Bangladesh in the 1980s and the 1990s. According to some estimates, over 1.3 million treadle pumps were sold to smallholder farmers in Bangladesh alone (Polak n.d.). The positive impact of the treadle pump on incomes and poverty reduction in Bangladesh was impressive. Several studies linked the adoption of the treadle pump to increased annual incomes varying from US$ 50 to US$ 500 (with a modal value of US$ 100) per year (Shah et al. 2000), and most smallholders were able to earn back their investment in less than a year (Polak and Yoder 2006).

Building on the positive outcomes in Bangladesh, International Development Enterprise (IDE), an international NGO, and other local NGOs started programs to disseminate treadle pumps in India from the mid-1990s onwards in areas where shallow groundwater was abundant and easily accessible (Rao 1996). One of these areas was the northern part of West Bengal in India, bordering Bangladesh, where conditions were similar to those in Bangladesh: high density of poor smallholders, surplus family labor, and ubiquitous shallow groundwater. The North Bengal Terai Development Project (NBTDP), one of the first projects promoting treadle pumps in India, sold 11,500 treadle pumps between 1995 and 2000 in Cooch Behar, Jalpaipuri, and Silipuri, the three districts in the northern part of West Bengal (van Steenbergen 2003). Several studies show positive impacts of these projects on farmers' income (Kumar 2000; Shah et al. 2000) and pumping and energy efficiency (Srinivas and Jalajakshi 2004). The treadle pump market potential in India as a whole was estimated to be between seven million (Indicus Analytics 2003) and ten million (Shah et al. 2000). Achieving this potential would mean over one billion US dollars per year in the hands of the poor (Shah et al. 2000).

Encouraged by the initial success in North Bengal, the NGOs increased their promotional efforts of the treadle pumps—with substantial financial backing from international donors—citing an increasing number of treadle pump sales to substantiate their assertion of the high demand for treadle pumps. The available estimates of potential demand for the technology only helped further substantiate their argument. At the same time, some evidence started to emerge that smallholder farmers had lost interest in this manual technology (Naik 2002) and had started accessing water through other means, such as renting diesel pumping sets (Polak n.d.). This, however, neither dampened the enthusiasm of NGOs in promoting the technology, nor of the donors in providing financial support.

Fifteen years after the first introduction of treadle pumps, the socio-economic and technological landscape in India has changed dramatically. Revisiting factors that contributed to its initial success, this study assesses if treadle pumps are an appropriate irrigation technology choice for smallholder farmers to adopt and for donors to support in the changed settings.

7.2 Study Area, Survey Design, and Methods

The study was carried out in the Cooch Behar district located in the state of West Bengal, India. The Cooch Behar district shares India's land locked international border with Bangladesh. The study area was chosen based on a number of considerations. First, marginal and smallholder farmers dominate the Cooch Behar district. According to the 2000/2001 agricultural census, 93 % of the total 309,371 holdings are below 2 ha. Groundwater is abundant and easily accessible (the groundwater table is between 2 and 5 m during pre-monsoon). These are ideal circumstances for both human operated and motorized pumping technologies. Second, the Cooch Behar district has a long—and still ongoing—experience in treadle pump promotion and use. The farmers in the district were among the earliest adopters of treadle pumps in India. In the early 1990s, treadle pumps were illegally brought in from neighboring Bangladesh, where this technology was first introduced (van Steenbergen 2003). Subsequently, donor supported programs to promote the use of treadle pumps were implemented, mainly by IDE through NBTDP (1995–2000), as described above. With the exception of a few interruptions due to donor funding, IDE-India has remained active in the area until recently and is reported to have sold over 8,000 pumps in the Cooch Behar district during the period from 2005 and 2009. Third, in the 1990s, the study district was one of the first areas to witness the influx of relatively cheap and lightweight Chinese motor pumps, unofficially brought in from Bangladesh and Nepal. With the electrification of the district, electrical pumps also became popular. Finally, the proliferation of motorized pumping (both electric and diesel) led to the emergence of a thriving water and pump rental market in Cooch Behar. In summary, the area has seen an evolution in pumping technologies and therefore is a good case to study treadle pump adoption and dynamics.

Table 7.1 Composition of the survey sample

Irrigation equipment	Number of respondents	%
Owns or owned treadle pump	60	22
Owns or owned motorized pump	120	44
Never owned pumping equipment	91	34
Total sample size	271	100

For this study, a survey was taken among a sample of 271 farmers from three blocks in the Cooch Behar district (Mathabanga I, Cooch Behar I, and Sitalkuchi) and examined treadle pump adoption over the period from 1990 to 2010. The blocks selected are locations where treadle pumps have been—or still are—being promoted. The breakdown of the sample of 271 farmers selected is given in Table 7.1. The sample is comprised of farmers who had either previously owned or still own a treadle pump (22 %), farmers who have invested in motorized pumps (44 %), and farmers who never owned any pumping equipment and depend either on the rental markets or practice rainfed farming (34 %). The survey addressed questions on the adoption dynamics and farmers' awareness, as well as preferences for and opinions of, various pumping technologies. In addition to the farmer survey, data was collected from observations during field visits, and semi-structured discussions with key informants (lead farmers, agricultural equipment suppliers and sellers, grass root level officials, mechanics (*mistris*), and other stakeholders). Primary data was cross checked and complemented from published and unpublished secondary data sources.

7.3 Results

7.3.1 Current Status of Use and Disuse of Treadle Pumps

Out of the 60 sampled farmers who once bought a treadle pump, only five (8 %) are still using them as the main source of irrigation. The vast majority (55 farmers or 92 %) have stopped using them for irrigation, though a few use their treadle pump occasionally as a standby arrangement (e.g., for priming diesel pumps or for drinking water purposes after dismantling one of the barrels). Table 7.2 gives the frequency distribution of farmers according to number of active years of use of treadle pumps. The results indicate that about 13 % of the farmers discontinued the use of treadle pumps after just 1 year and more than 50 % after 4 years. On the other hand, 19 % of the farmers surveyed maintained their pumps for irrigation purposes for 8 years or more. Overall, the average period for treadle pump use was just under five years.

In the survey site, a pattern of dis-adoption of treadle pumps became noticeable beginning in 2003, and by 2006, almost 53 % of treadle pump owners either had stopped using their treadle pumps or used them only occasionally (Table 7.3). The

Table 7.2 Number of years of use of treadle pump as a main source of irrigation

Total number of sampled farmers		60
Number of farmers who are still using treadle pumps as the main source of irrigation		5 (8 %)
Number of farmers who stopped using treadle pumps or relegated treadle pump to secondary position		55 (92 %)
Number of years of use	**Number of farmers**	**%**
1	7	13
2	5	9
3	9	16
4	7	13
5	7	12
6	6	11
7	4	7
8	2	4
>8	8	15
Total	55	100
Weighted average years of active use	4.85	

Table 7.3 Temporal pattern of disuse of treadle pumps

Year stopped using treadle pump as the main source of irrigation	Number of farmers	%
Before and up to 1994	2	4
1995–2002	7	13
2003–2006	20	36
2007–2010	26	47
Total	55	100

pace of abandonment further accelerated between 2007 and 2010 with approximately 47 % of sampled treadle pump owners dis-adopting the technology during that period. Additionally, out of the nine persons who purchased a treadle pump between 2007 and 2010, 3 persons (or 33 %) also abandoned the technology during that period.

Two main factors have contributed to the observed pattern of dis-adoption: availability of affordable motor pumps (including rental markets) and the increased costs of labor. These factors are described in more detail below.

First, before 2002, diesel or electric pumps—though present in the region—were not common due to the lack of availability in the market, high purchase price, high operational cost (fuel), and the small fragmented landholdings of the majority of households. Electricity connections for irrigation pumping were few and if available, reliability of electricity supply often was problematic. Only a handful of large farmers could afford owning motor pumps. Rental markets for diesel pumps and water markets did not exist, in part due to the heavy weight of diesel engines, making it difficult to transport them for rental. Small farmers, therefore, had little or no choice other than using manual water lifting methods, such as treadle pumps, or practicing pure rainfed farming. From around 2002 onwards, the area saw a large influx of mechanized pumps. Small, cheap, and lightweight Chinese-made petrol/diesel pumping sets started making inroads in the Cooch Behar district, initially smuggled over the Bangladesh border, later legally imported. At the same time, the expansion of electricity connections to rural areas encouraged investments in electrical pumps. Indian manufacturers of diesel engines facing competition from imported Chinese diesel engines developed lighter weight, better quality, and relatively cheaper versions of diesel engines to regain part of the market share. A market for secondhand pumps and spares for Indian pumps is now emerging. As a result, a variety of affordable, lightweight, and easily transportable motor pumps became widely available and as a spin-off, informal—but competitive—pump rental markets emerged. Through these markets, motorized pumping became accessible to smallholders who could not afford to invest in their own pump.

Second, because of increasing prospects for employment, both within the agriculture sector (due to increased availability of irrigation) and outside agriculture sectors (in services such as rickshaw pulling), labor became scarce and expensive. This trend was accelerated by the implementation of an employment-generating program—Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) of Government of India.[1] Opportunity cost of family labor and costs of hired labor increased, making labor-intensive technologies such as treadle pumps less attractive.

Both trends are clearly reflected in our study results. However, when asked about the reasons for disuse of treadle pumps, a majority of the dis-adopters mentioned issues related to unavailability or high price of labor (Table 7.4). Nearly all of those who stopped using treadle pumps (53 out of 55, or 96 %) now have access to water by renting motorized pumping equipment. Only two of them stopped using irrigation water entirely and switched to rainfed farming. None of them bought a motor pump. However, given the opportunity, about 77 % of the former and present treadle pump owners indicated that they would aspire to purchase a motorized pump (diesel or electricity operated), but the high purchase and running costs combined with the lack of access to finance are the main obstacles (Table 7.5).

7.3.2 Uptake Potential of Treadle Pump Technology

Given the pace at which the owners of treadle pumps have been abandoning the technology, do treadle pumps hold any promise in the future? The potential demand for treadle pumps can come from two groups of farmers: (i) those that have used this technology in the past but abandoned it subsequently, as discussed above; and (ii) those who have not so far invested in any irrigation technology.

[1] The MGNREGA is a poverty alleviation program in which the Indian government guarantees 100 days of paid labor for those willing to do unskilled work.

Table 7.4 Factors that have contributed towards disuse of treadle pumps

Total number of sampled farmers			60
Number of farmers who have stopped using treadle pumps			55
Number of farmers who are still using treadle pumps			5
Factors that contributed to decision on discontinuing use of treadle pumps as primary source of irrigation		Number	%
Treadle pump related technological factors	After purchase realized treadle pump is useless technology so stopped using it	6	11
	My treadle pump had lived its life and had become unserviceable	3	5
	Lack of spares and service facility/high cost of repair	0	0
Water output	Water output is very low—insufficient for my size of land holding and/or cropping pattern	18	33
Water level	Water table has gone down—treadle pump unable to lift water	5	9
Labor	Not enough family labor, family refuses to treadle, hired labor for treading not available or expensive	34	62

Note Totals may not tally due to multiple answers

Table 7.5 Factors dissuading farmers from investing in motorized technology

Total number of farmers		60
Number of farmers willing to invest in a motorized technology		46
Reasons for not investing	Number of farmers	%
High cost of technology	20	43
Quality of technology (quality, life of equipment, lack of dealer guarantee on equipment)	8	17
O&M cost (spare parts not available, cost of repair high, mechanics not available for repair)	4	9
Availability (of equipment, diesel) a problem	2	4
Lack of access to finance for meeting the cost	23	50
Any other	2	4

Note Totals may not tally due to multiple answers

We asked the 60 farmers, who have had experience in treadle pump ownership and use, if the technology holds any promise for the future and if so, what can be done to improve and rejuvenate the treadle pumps technology. All but three respondents indicated that given the technology options available currently, there is no hope for revival. The three more optimistic farmers thought that if the treadle pump could be re-engineered and motorized, some farmers might return to using them. However, technical challenges aside, motorizing treadle pumps would defeat many of the benefits originally gained from the treadle pump (e.g., fuel-free technology).

Table 7.6 Non-ownership of irrigation equipment and methods of irrigation

	Number	%
Total number of sampled households	91	
Number of households who do not irrigate their crops	13	14
Number of households who irrigate their crop	78	86
Sources of irrigation used by farmers who irrigate their crops		
Rented treadle pump	0	0
Rented diesel pump	65	83
Rented electric motor	13	17
Buy water from others	0	0

Our sample comprised of farmers, one-third (91 out of 271) of whom have never owned pumping equipment (human operated or motorized) and could therefore be potential users of treadle pump technology. Currently, this group of farmers either rents irrigation equipment (86 %) or undertakes rainfed farming (14 %). Of the renters, a large majority (83 %) rents diesel pumps; none of them rents treadle pumps. Table 7.6 provides details.

With increasing sales of diesel pumping sets in the region and the fast developing rental markets, the availability of equipment for rent has improved, rental rates have become competitive, and rental of equipment has become an affordable and economically attractive option. Some of those who rent equipment do so as a deliberate choice; others may want to buy their own equipment but face obstacles to do so. When asked why they did not buy their own pumping equipment, more than two-thirds of the non-owners indicated that lack of finances kept them from buying equipment. Nearly one-third explained that they could rent equipment from neighbors or the market (Table 7.7). Note that awareness about technology choice was not perceived as a problem.

Of the 91 non-owners, 13 % indicated that they were not even interested in buying equipment, even if some of the above concerns were addressed (Table 7.8). Of the remaining 87 % willing to invest, all farmers expressed their preference for motorized pumps. A small majority expressed their preference for electric pumps (as opposed to diesel pumps), while few farmers would like to invest in both. This is not surprising, given the comparative economics of electricity as compared to diesel pumping.[2] The preference for diesel is due to the non-availability of electricity connections and the fact that diesel pumps are easier to transport.

None of the sampled households gave preference to treadle pumps. This is remarkable given the low price of treadle pumps and the lack of finances to purchase motorized pumps. Treadle pumps are specifically designed for this group of poor smallholders. Farmers gave many reasons for their unwillingness to invest in treadle pumps (Table 7.9). The most important of these relates to labor, either

[2] It is a common finding that electricity is a preferred source of energy for pumping because it is cheaper than diesel and electric pumps are better quality and more efficient (see among others Shah 2009).

Table 7.7 Factors constraining investment in irrigation equipment by non-owners

Factor group	Specific factors	Number	% of non-owners
Total number of sampled households		91	
Reasons for non-investment			
Physical	Small size of land holding	19	21
Water access/ availability	Enough rainfall—irrigation not required	0	0
	No surface water in the vicinity	1	1
	Irrigate using gravity flow of surface water	0	0
	Groundwater table very deep	1	1
	Cultivate low water using crops	1	1
	Irrigate using buckets etc.	1	1
Water market	Equipment available for rent from neighbors/market	28	31
	Water available from neighbors for purchase	7	8
Financial	No money to invest	62	70
	Credit facilities not available	14	16
Technological	Lack of awareness about different technologies	3	3

Note Totals may not tally due to multiple responses in some cases

Table 7.8 Willingness to invest in irrigation and favored choice of irrigation technology

	Number	%
Total number of sampled households	91	
Number of households who would not like to invest in an irrigation technology	12	13
Number of households who would like to invest in an irrigation technology	79	87
Preferred irrigation technology		
Treadle pumps	0	0
Rope and washer pumps	0	0
Diesel pumping sets	38	48
Electric tubewell	45	57
Any other		

Note Totals may not tally due to multiple choices

non-availability or the high cost of labor and health related problems of treading. Part of this may be due to demonstration effect. Some of these farmers have seen and discussed the use of treadle pumps with neighboring treadle pump owners. Based on their neighbors' experience they made their own assessment and decided against investing in this technology. In fact, 56 % of the farmers dubbed the treadle pump as a "technology without future".

Table 7.9 Factors inhibiting the choice of investment in treadle pump

Total number of sampled farmers		91	
Number of farmers willing to invest in irrigation technology		79	
Number of farmers indicating treadle pump as their most preferred choice		0	
Factors inhibiting treadle pump as a favored choice		Number	%
Demonstration effect	Neighbors/friends purchased treadle pump but are not happy using treadle pump	37	47
Technological factors	Useless technology—has no future	44	56
	Irrigating with treadle pump is very time consuming and slow process	35	44
	Concerns relating to poor quality of treadle pump available, problems of spare parts availability, after sales services etc.	15	19
	Cannot draw water from greater depth	3	4
Water output	Water output is very low—insufficient for my size of land holding, not suitable for water intensive crops	45	57
Labor	Not enough family labor, family refuses to treadle, hired labor for treading not available or expensive	70	89
Health	Treading causes pain in joints	51	65
Cost and access to credit	Expensive, not enough money to invest, lack of access to credit	4	5
Renting out	Limited scope for renting out	13	16
Availability	No treadle pump dealer in the vicinity	0	0
Gender	Not gender friendly—women find it difficult to treadle, women resent investment in treadle pump	7	9
Economic and social prestige	Uneconomic to invest in treadle pump—cost of irrigating with treadle pump is more than the revenue it generates through increased crop yields	5	6
Others		0	0

Note Totals may not tally due to multiple answers

7.4 Conclusions and Lessons Learned

The treadle pump is a useful and affordable technology and offers great potential for raising incomes of resource poor farmers through provisioning of water for irrigation at a nominal cost. The evolution and dynamics of pump adoption in the Cooch Behar district holds some important lessons that are relevant beyond the study area as well.

While not undermining the immense utility of treadle pumps, it has to be kept in view that the choice of technology is not a once for all decision. Technology adoption is a dynamic process, and the success of a technology in one location at one point in time does not guarantee its uptake in another location at another point in time, even if the physical and social environment is similar. Circumstances and conditions to successful adoption change over time. Treadle pumps were hugely popular among smallholders in Bangladesh in the late 1980s and 1990s, but rising wages and the increasing availability of alternative options made treadle pumps the least preferred option among smallholders in West Bengal 20 years later.

The adoption of irrigation technology does not necessarily follow a linear path from ‘simple’ manual methods to ‘advanced’ motorized technologies. This linear path is sometimes referred to as the ‘technology ladder,’ which implies that hand watering with buckets followed by treadle pumps are necessary stepping stones in the adoption process of motor pumps because they allow smallholders to amass sufficient irrigation experience and monetary means to be able to buy a motor pump. In our study, we did not find evidence of the technology ladder, nor for treadle pumps as a stepping stone technology. In fact, most of the first-time motor pump owners were pure rainfed farmers prior to taking up irrigation. Nearly all former treadle pump users switched to water and rental markets rather than buying a motor pump. Apart from former treadle pump users, a majority of the farmers relying on rental markets were first-time irrigators. Therefore, technology uptake reaches existing and new irrigators through multiple entry points.

Ownership is not a necessary precondition for technology access. Even if motorized pumps are too expensive for smallholders, they can still have access to motorized pumping through rental markets that emerged following demand from non-owners. More recently, the evolving secondhand market for pumps and spares further increased options for those not able to afford a new motor pump.

Low cost and affordability are not necessarily the determining factors for smallholders to invest in a certain technology. Other aspects, such as the availability and accessibility of alternative options, play an equally important role. Our survey results showed that the majority of smallholders who could not afford to buy a motor pump did not invest in an inexpensive and affordable treadle pump, even though their adoption is highly profitable. Because of labor constraints, most prefer renting equipment on available rental markets though it is slightly more expensive.

Lack of access to finances was cited by a majority of farmers as the major obstacle to investing in the technology of their choice. Provision of credit for irrigation technology at soft terms may provide a boost to private investment and access to irrigation.

Pump sales are a weak indication of adoption rates. Sometimes numbers of sales are used as proxy for treadle pump adoption and hence as an indicator of impact of promotional activities. Given the high dis-adoption rates, this may give an inflated picture of the actual impact of treadle pump promotion on poverty reduction. Regular and independent monitoring in the field is necessary to understand the changing landscape of smallholder irrigation and to assess the role of technology promotion in development. This will ensure that the technologies desired most by beneficiaries—not just by promoters—get the support and promotional backing of the donors and governments for effective poverty reduction.

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Chapter 8
Toward a New Approach for Hydrological Modeling: A Tool for Sustainable Development in a Savanna Agro-System

Theophile Mande, Natalie Ceperley, Steven V. Weijs, Alexandre Repetti and Marc B. Parlange

Abstract Agriculture in Tambarga, a small, remote village in the landlocked country of Burkina Faso, is dependent on the seasonally variable local hydrology. Extreme seasonal and spatial variability of rainfall significantly impacts the livelihood of farmers, who depend mainly on rainfed agriculture. This dependence on rainfed production makes them particularly vulnerable to meteorological conditions, and they continually experience food insecurity. The groundwater is promising as storage to mitigate effects of drought. However, because of its interaction with the various hydrological components, we need to better understand all the processes to fully assess the impacts of possible solutions. Hydrological and meteorological data were collected over a two-and-a-half-year period in the catchment adjacent to the village (area = 3.5 km^2) to address these issues. The field studies show that the major portion of storm runoff was generated in the upper savanna basin, while baseflow appears to be mostly originating from the downstream agricultural field. The seasonal cycle of groundwater appears to control the stream flow and therefore, the continuous flow over the entire stream occurred when the water tables became interconnected and surfaced the ground level. Additionally, this paper discusses water management scenarios (open dam, deeper wells and buried dam) for agricultural purposes using a simple and comprehensive hydrological model. Simulations based on reducing evaporation rate by

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keeping the water underground present a solution that could improve agricultural production, and therefore, reduce vulnerability of Tambarga's farmers to climate change.

8.1 Introduction and Purpose

Groundwater storage is a promising strategy to mitigate the consequences of drought in West Africa. Thousands of open dams were built in the Volta basin with the aim to store water for livelihood in Burkina Faso since 1960. However, the flatness of the country, in addition to the high evaporation rate in this region, means water loss in open dams is significant. Additionally, the high rate of particle transport during the rainy season over this region leads to the sedimentation of the dam with the consequence of reducing the storage capacity. Therefore, the open dams are not adapted for sustainable water management in the arid and semi-arid countries, as mentioned at the Earth Summit in Rio de Janeiro in 1992. Onder and Yilmaz (2005) noted that to tackle surface water scarcity, the groundwater represented the only sustainable resource for arid and semi-arid zones.

The sustainable management of groundwater resources requires a complete understanding of its interactions with the runoff, soil moisture, and evaporation (Gribovszki et al. 2010; Irvine et al. 2012). The processes that occur during groundwater recharge are complex because of the interactions between different variables such as rainfall, soil, runoff, evaporation, initial soil moisture, canopy cover, cloud cover, wind speed and solar radiation. These parameters vary in space and time and thus collecting accurate spatial and temporal data is elusive. Techniques that exist, such as radar, are very expensive, difficult to implement, weather-dependent, need frequent maintenance and therefore, are not feasible for poor countries.

Hydrological modeling is recognized as a powerful tool for the management of water resources at local, regional and continental scales (Beven 2004; Brutsaert 2005; Gnouma 2006; Ioslovich and Gutman 2001; Simoni et al. 2011). These models, which range from empirical lumped models to fully distributed models, are suitable for forecasting runoff, floods and droughts, and can be applied to evaluate water management strategies (Simoni et al. 2011). The accuracy of modeling is related to its ability to reproduce as close as possible the processes occurring in a delimited area. The accuracy is also related to the researchers' understanding of the processes and their abilities for calibration. The lack of available and accurate data is a limitation for most of the distributed and semi-distributed models in Africa. Several scientists have developed simple models using monthly aggregated data that are widely available (Ndomba et al. 2008). These models seem to give good results overall, but are not adapted to the intensive rainy season (4 months) and rain events (less than 1 h) that we find in Tambarga, and thus fail replicate the timing rainfall-runoff response.

Many authors have highlighted the sensitivity of modeling to several factors like landscape, land use, relief, soil, topography, plant characteristics, groundwater patterns and anthropogenic activities (Brutsaert 2005; Gnouma 2006; Simoni et al. 2011). The reliability of hydrological modeling for forecasting purposes is affected by the accuracy with which spatial and temporal distribution of forcing is known. To understand the processes that take place in a basin remains a crucial step for models. Therefore, highlighting and understanding the hydrological processes appears to be a way to achieve successful modeling and subsequently, propose sustainable water management strategies. The objectives of this research are: (1) to explore the subsurface flow processes and explain the hydrograph patterns and their links with groundwater behavior and (2) highlight some possible results-based tools for improving food security for the local population through hydrological modeling.

8.2 Design and Methods

Tambarga is located in the commune of Madjoari, the province of Kompienga in the southeast part of Burkina Faso (11°26′42.79″N, 1°13′32.09″E) at the border with Benin in the Soudano-sahelian zone (Fig. 8.1).

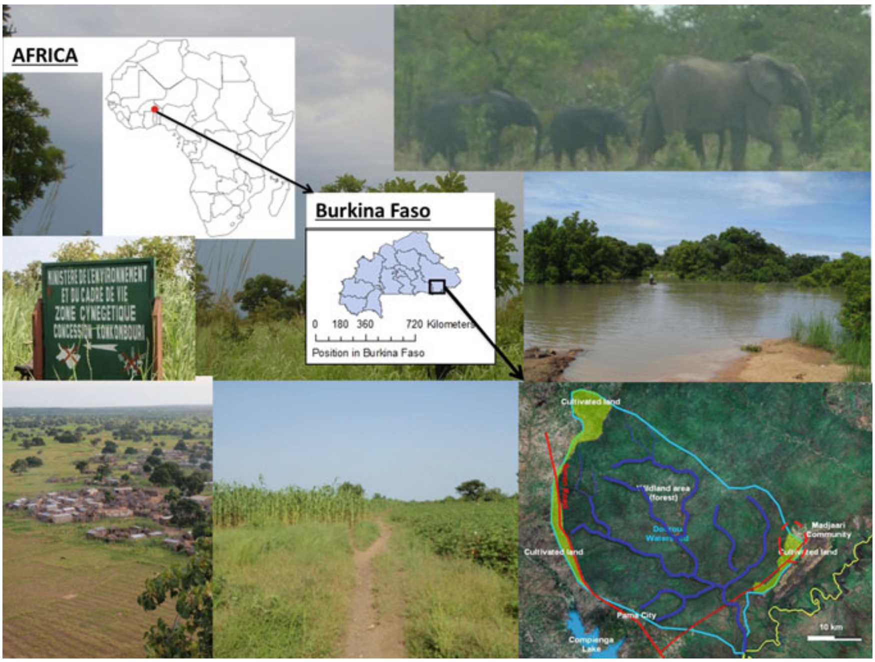

Fig. 8.1 Trial site Madjoari in southeastern Burkina Faso

Madjoari is composed of eight villages and more than twelve temporary houses (*hameaux de cultures*). The Gourmantche are the ethnic majority but there are also other ethnicities like Mossi (migrant framers), Peulh (breeders), Haoussas, Djerma and Yanas (traders). Agriculture is the main activity in Madjoari city and involves almost all of its population. The village is part of a protected hunting zone, rich in biodiversity: wildlife (lion, elephants, buffalo, hippopotamus, wild boar, etc.), and vegetation (*Sclerocarya birrea, Adansonia digitata, Annogeisus leiocarpus, Bombax constatum, Burkea africana,* etc.) (Ceperley et al. 2012; Commune Rurale de Madjoari 2009).

The annual average rainfall is between 900 and 1200 mm but can shift quickly to extreme values from one year to another (< 300 or >1500 mm) (Ceperley et al. 2012). The rainfall pattern at Tambarga is monomodal with a rainy season from May to August, followed by the dry season from September to April. The rainfall distribution in time is variable according to the year. Two phases of rainfall have been identified in 2010: (1) May to mid-July was characterized by sparse rain and (2) from mid-July to August, the season with frequent rain (>1 rain event/2 days) was completely established.

The Tambarga watershed has an area of 3.5 km^2 and is subdivided in three geomorphological units: (1) an upper basin (2 km^2) characterized by a grass open savanna forest, a “lithosol” soil with a rocky escarpment, and shallow perched groundwater, (2) a lower basin (1.5 km^2) characterized by a millet field with sandy soil, sparse trees and deeper watertable and (3) the bottom basin (0.1 km^2) a part of the field basin characterized by loamy clay soil, used as rice fields with a shallow perched groundwater. The altitude in the watershed ranges from 200 to 400 m and the basin is about 700 m wide along most of its length.

A field experiment has been conducted since April 2009 to provide a comprehensive dataset aimed at investigating the hydrological processes and modeling the stream flow. Measurements were taken during three rainfall seasons in 2009–2012. The measurements were taken in both a “natural savanna” section and an adjacent “agricultural” section. This involved measuring hydrological, meteorological and soil data at high spatial and temporal resolution. Data were acquired with advanced research equipment such as SensorScope environmental monitoring stations, two weirs and eddy covariance fluxes stations.

8.2.1 Hydro-Meteorological Variables: Sensible, Latent Heat Flux and Discharge

Tambarga, as is typical of villages in West Africa, experiences with high temperatures (>45 °C in April) and therefore high evaporation rates. Additionally, the flatness of the country does not allow for capturing and storing water for users. Evaporation is therefore a crucial parameter to understand and estimate. Evapotranspiration, the combined effects of water loss through both evaporation from free water surfaces into atmosphere and transpiration from vegetation, is a complex process dependent not only on climatic variables (e.g., solar radiation, wind speed, rainfall), but also on geographical variables (e.g., local vegetation, slope, elevation, aspect, etc.), plant physiology (e.g., stomata1 resistance), and soil properties (e.g., soil moisture deficits, hydraulic conductivity, etc.) (Stagnitti et al. 1989). Eddy covariance techniques allow for accurate measurements of the sensible flux and latent heat flux (evaporation) (Brutsaert 2005). Two sets of Eddy covariance towers were installed respectively in the agricultural field to evaluate the influence of cultures on daily and seasonal patterns, and on the hill edge of the open savanna forest to capture the influence of trees on evaporation. Each tower records the wind velocity, air temperature and water vapor concentration data at 20 Hz in order to calculate the fluxes. For this study, the data from the tower on the agricultural field was used. The latent heat flux (LeE) was computed using the covariance of vertical wind fluctuations (w) and specific humidity (q) multiplied by the latent heat of vapor (Le) and air density (ρ) (Eq. 8.1). The evaporation (mm) is obtained simply by conversion of the latent heat flux (w/m^2).

$$L_eE = L_e\hat{\rho}\overline{w'q'} \tag{8.1}$$

Before performing any hydrological modeling or implementing any water management strategy it is crucial to be able estimate the amount of water flowing over the considered basin. For this purpose, we used weirs to measure the discharge. Discharge was measured at two levels in the basin: (1) using 90° V notch weir at the outlet of the upper basin and (2) a mix-triangular-rectangular weir in the agricultural flat basin. Stage at each weir was measured and recorded every minute by using automatic pressure sensors (manufactured by MADD Technologies, Switzerland) and converted to streamflow through a discharge rating curve (Eq. 8.2). The rating curve was obtained by combining measurements of water level over the weirs crest and in situ measurements of discharge by salt dilution method.

$$Q_{up}(h) = 1.414^{*}h^{5/2}\left(m^3s^{-1}\right); Q_L(h) = 6.27^{*}h^{3.68}\left(m^3s^{-1}\right); \tag{8.2}$$

where Q_L and Q_{up} are the discharges respectively at the lower and upper basins in m^3 s^{-1} and h is the water level on the crest in m.

8.3 Results

Figure 8.2 shows a relatively weak daily evaporation (average (μ) ~4 mm/day; standard deviation (σ) ~1 mm). We found evaporation to increase during the rainy season. This trend is related to the increase of available water and the foliage of the numerous deciduous trees, crops and grasses growing (Bagayoko et al. 2007). Two peaks of evaporation rate were identified in June (high rainfall event, grass and crop growing) and September (frequent rainfall event). The latent heat

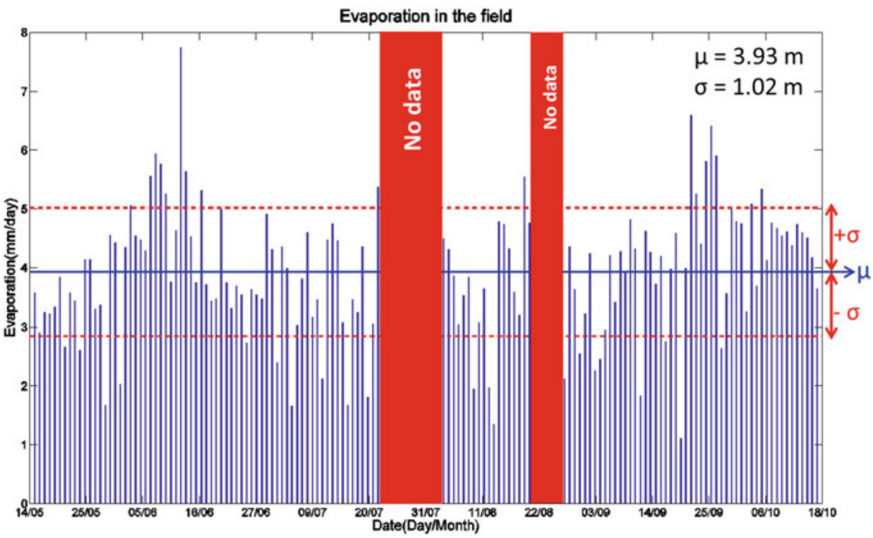

Fig. 8.2 Daily evaporation at Tambarga

flux, represented by the evaporation, is the most important term (71 % during the rainy season) of the energy balance at Kompienga (Bagayoko et al. 2007). This important rate of evaporation is mainly a result of the high temperatures occurring in the region, which leads to increased plant transpiration. The mean daily air temperature in 2010 is 35 °C within a range of 20–45 °C in April.

The yearly (dry and wet season) pattern of evaporation is important for understanding the interrelationships between the variables that have effects on agriculture: net radiation, wind speed, antecedent soil moisture and root depth. Unfortunately, for technical reasons we do not have data for the dry season and some periods during the rainy season that would allow us to draw conclusions on the sensible and latent flux pattern for a complete year. Knowing that the net radiation is the primary source energy of evaporation (Bagayoko et al. 2007; Brutsaert 1982, 2005; Ojo 1983), the strong net radiation observed at the site allow us to assume that the evaporation could increase during the dry season. Therefore, it is clear that water storage will only be effective if high evaporation rates are counted as significant component in water management strategies.

The second relevant variable for water resources management is stream flow. The river studied is characterized by a length of 2.5 km, a width range between 2 and 7 m, and a 1 % slope (in the agricultural field) and a 7 % slope (in the upper savanna forest). The river is ephemeral and started to flow with the rainy season onset but remained hortonian until groundwater was recharged. The discharge observed varied from 0 during the dry season to approximately 0.6 m^3s^{-1} (the maximum discharge observed during rainy season in 2010). Regarding the streamflow distribution between the two geomorphological units, the upper basin contributes to about 50 % of the total surface runoff. The geology, mostly rocky on the edges, increases the surface runoff over this area. The topography of the upper basin, corresponding to a canyon (transversal slope >12 %), is adaptable for storing water by constructing an open dam.

8.3.1 Groundwater and Streamflow

Groundwater storage is a promising strategy to mitigate effects of drought in West Africa. In Tambarga potable water is provided only by wells and therefore, understanding how the groundwater recharge occurs and how much water can be stored is crucial for the local population drinking water supply. Six wells were monitored in the agricultural basin with the aim to understand this process; the wells are distributed over a transverse cross-section on the left bank (from the basin boundary toward the river bed) over a 200 m distance. The groundwater is characterized by two shallow perched water tables in the bottom rice field and the upper savanna basin and one deeper water table in the intersection between these two (Fig. 8.3).

The watertable recharge pattern is divided into two periods. During the first period, between the onset and mid-August, the groundwater was stable. The water requirements for humans, plants and evaporation were more or less equal to the recharge rate. A significant recharge moment was found during the second period, between mid-August and October, when the groundwater rose suddenly and reached the ground level, which resulted in an increasing streamflow. Three permanent and more than four seasonal springs were found throughout the basin.

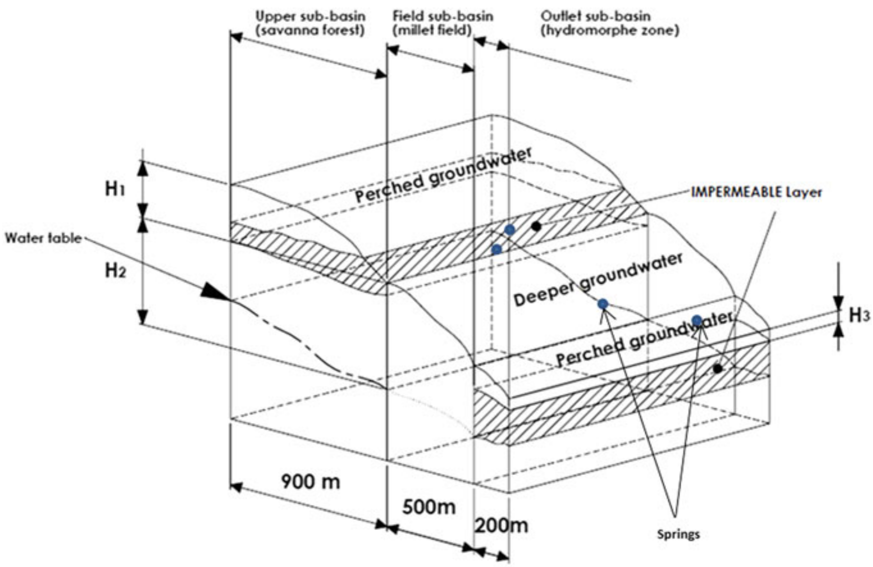

Fig. 8.3 Groundwater distribution

The seasonal springs appeared when the rainfall events became more frequent (>1 event per day), the soil moisture approached to saturation, and the overall watertable interconnected over the basin. The distribution of springs within basins during base flow is well known to be a good indicator of subsurface water flow paths (Komatsu and Onda 1996; Onda 1994; Onda et al. 2001).

The watershed runoff was generated by rainfall and controlled by the groundwater. Seasonal cycles of groundwater recharge appear to control the stream flow and are damped by storage and evapotranspiration on the agricultural basin. Brutsaert (1982) showed that the first saturated layers of shallow groundwater are influenced by the atmosphere and subject to evaporation.

The analysis of the runoff dynamics highlighted the distribution of surface runoff and base flow according to the land use. Intermittent or truncated responses of streamflow were identified over the course of the season in 2010. Three phases were identified (Fig. 8.4). First, after ten rain events with more than 210 mm in accumulation, the flow started to be continuous between springs 1 and the outlet of the basin (5–31 July) over nearly 200 m of the river. This flow is caused by the filling from the bottom by shallow groundwater. Second, from 12 to 15 August after twenty daily rain events were recorded with 360 mm of rainfall, the flow became continuous between springs 2 and 3 and the triangular weir in the upper basin (Fig. 8.4). These flows seeped away into the ground directly downstream of the weir, where the soil acted like a deeper storage tank. Third, from 15 August to the end of October, when the intermediate storage tank became filled, the perched groundwater of springs 2, 3 and 1 became interconnected, which induced the continuous flow throughout the full 2.5 km of the river. The watertable distribution showed that the middle part of the basin represents an option for water storage underground. The cross-section between the deeper watertable and the lower perched groundwater could be the location to build a buried dam aiming to reduce the underground outflow, minimize the evaporation and stored water for crops and plants.

8.3.2 Implementation

Food insecurity affects a large portion of the population in sub-Saharan Africa and Tambarga. To meet future food requirements, current rainfed farming systems need to increase yield output. One way is to improve water and fertilizer management in crop production (Fox et al. 2005). Understanding the hydrological processes appears to be another way to improve water management at Tambarga and reduce the population's vulnerability to climate change because less than 10 % of water resources are exploited in this region (Ceperley et al. 2012). To improve understanding of the hydrological processes at Tambarga's catchment, a simple lumped conceptual model with three sub-areas was developed. The catchment was subdivided based on dominant land use, soil type and peak flow observed in the field. The main components of the model are: rainfall, soil moisture, evaporation,

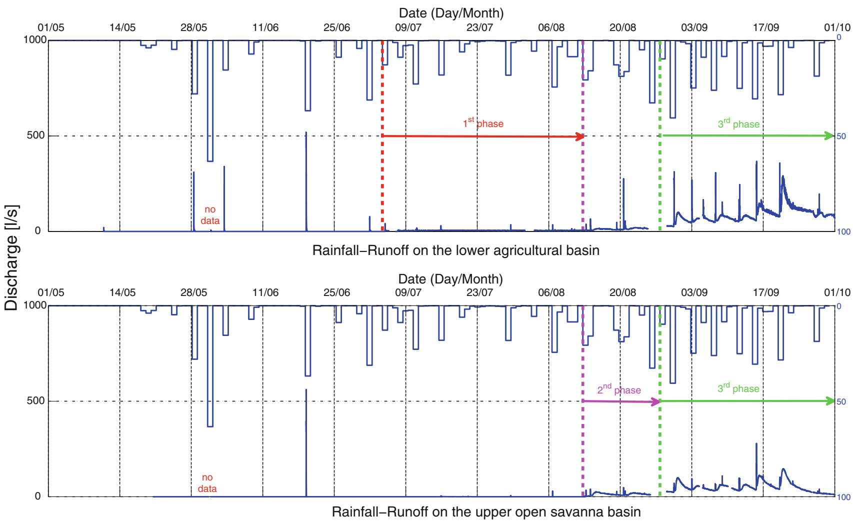

Fig. 8.4 Streamflow phases over the rainy season

groundwater depth and discharge (Fig. 8.5). The model is used to simulate runoff, soil moisture, and groundwater to quantify the effects of irrigation on the local water balance. All the components are interconnected through linear processes. The interconnections are controlled by thresholds defined for soil infiltration capacity, rainfall intensity, hydraulic conductivity at saturation and groundwater depth. Reaching a particular threshold leads systematically to the generation of runoff, infiltration, or a recharge of the water table.

Initial simulations of runoff produce satisfactory results for the beginning of the rainy season when the soil is dry, but runoff is overestimated when the rainy season is completely established with a permanent stream flow (Fig. 8.6).

The model is able to account for the subsurface flow and reproduce the groundwater recharge pattern. The first results allowed us to conclude that the basin provides a significant amount of groundwater that could be used for irrigation to improve crop yield and consequently, reduce food insecurity. Three scenarios for storing this water are tested in this work: (1) Dams at the outlet of the open savanna forest (upper basin), (2) deeper wells for irrigation in the field and (3) dams buried to retain the water for the plants and crops in the field.

The first scenario, with a dam at the first outlet, could lead to capturing a significant amount of water for irrigation. The dam would be located in the river cross-section at the outlet of upper savanna sub-basin (290 m a.s.l.) (Fig. 8.7). The proposed dam is 20 m in height, for a coverage area around 107,838 m^2 and around 2 million m^3 of water storage capacity. The water provided by this dam could be used for irrigation of 50–100 ha of parcels, which would benefit more than 200 to 400 stakeholders by increased income for more than 200 households. These first estimations highlight the usefulness of the dam and how it could

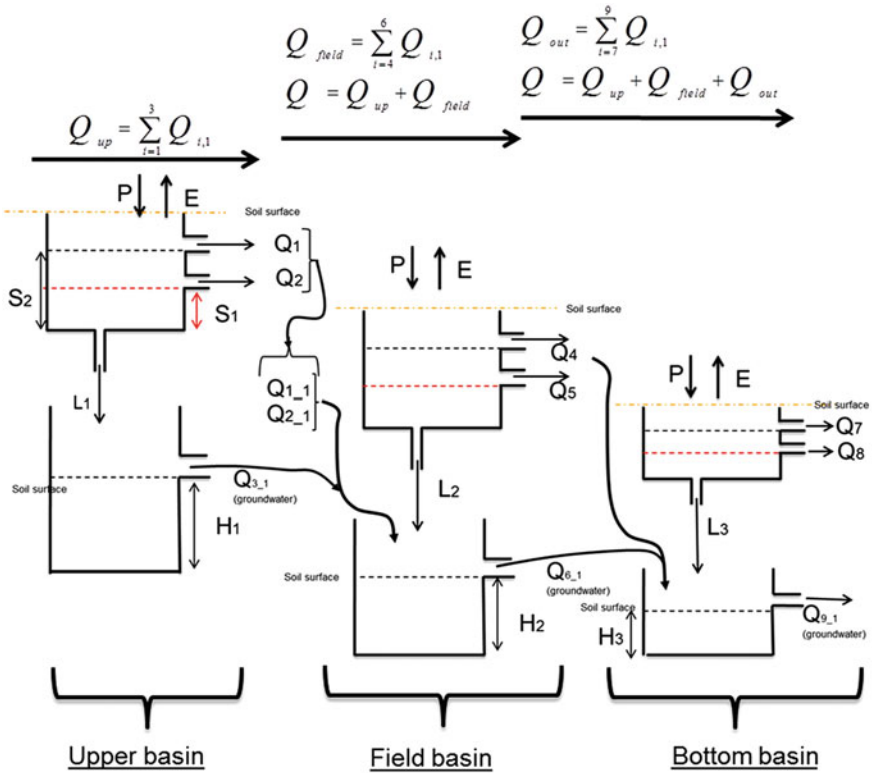

Fig. 8.5 Model diagram

improve food security for local people. However, work is still needed to quantify exactly the amount of water that would be evaporated, and the overall impact on the local hydrology. Additionally, special attention should be devoted to the environmental impact with respect to the relative richness in trees in the upper basin and its social services.

The second scenario (Fig. 8.8), of deepening wells, has already been tested by the local population. They found the shallow depth of the wells and the instability of the soil structure increased the difficulty of the project, which led to an abandonment of this irrigation strategy. Nonetheless, the deeper wells proposed in this paper could be a solution to at least, minimize water unavailability and allow for better crop production. The proposed wells could range in between 20 to 40 m and could be installed in the cross-section indicated in Fig. 8.8. They could provide an average 48 m^3 per day of water, which can irrigate 20–30 ha of crops and benefit 100 households. The wells must be stabilized by concrete and protected to avoid chemical contamination because farmers use fertilizers to improve crop yield. Attention should be paid to the long-term sustainability of this intervention, since the main source of drinking water is the groundwater.

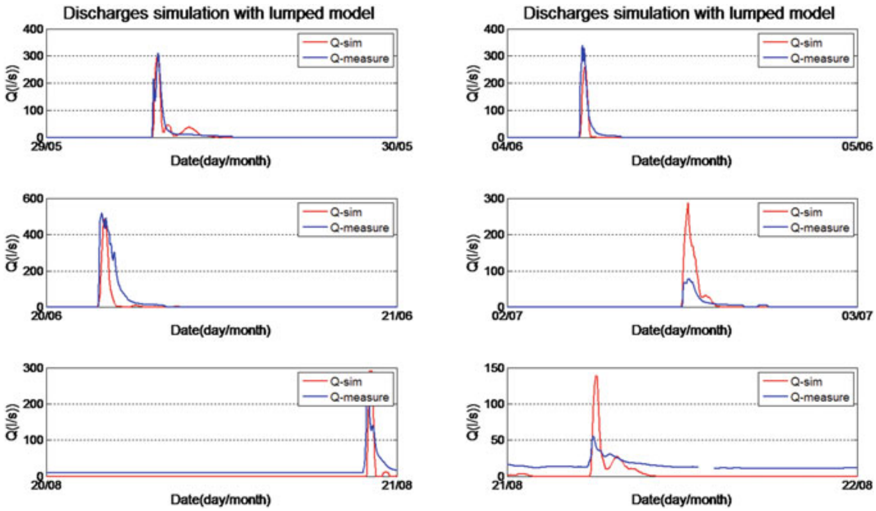

Fig. 8.6 Rainfall-runoff

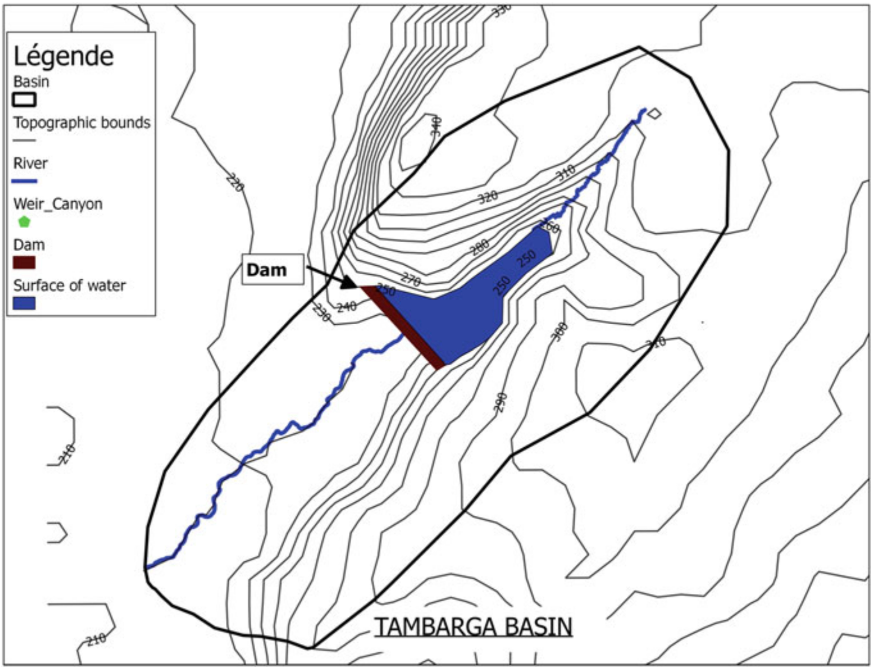

Fig. 8.7 Open dam

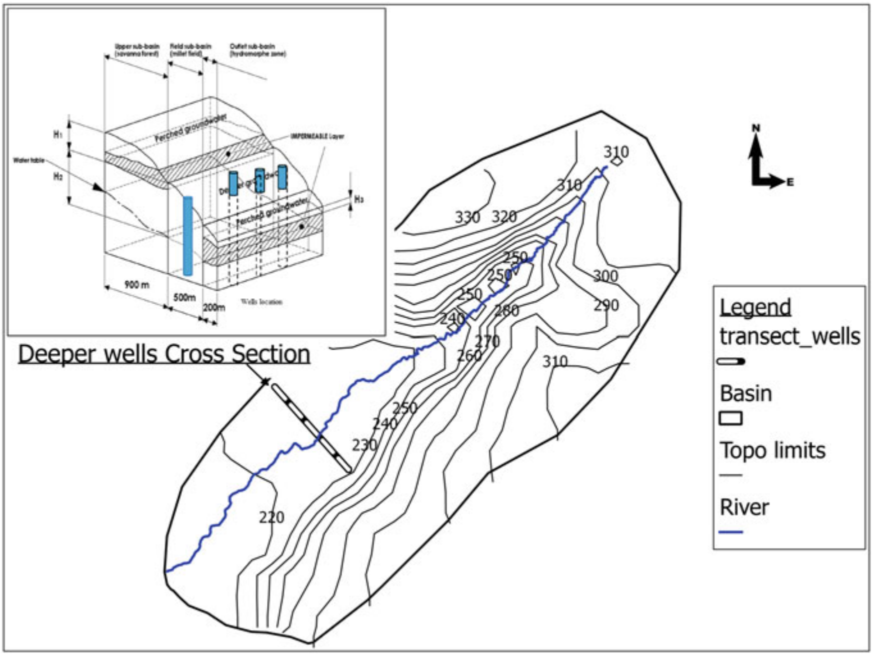

Fig. 8.8 Deeper wells

The third scenario (Fig. 8.9), with a buried dam, could be relatively cheap (∼5,000 US$) or very expensive depending on the material used. Using local materials, such as clay, for waterproofing the dam section would be cheaper, while concrete would be very expensive (>50,000 US$). The buried dam principle consists of building an impermeable wall in a trench dug over a cross section in the basin whose bottom limit corresponds to the impermeable layer. Basically, the dam depth would range between 6 to 10 m over 100 m length. It would reduce the direct evaporation on the order of 99 % compared to the open dam scenario. The buried dam would lead to an increase of the soil moisture in the field part of the basin and help to fight against dry spells by providing water to the plants and crops directly through the soil. Dry spells lead to a significant decline of rainfed production (Fox et al. 2005). However, this production reduction depends also on the crop development stage that is affected. Increasing the water level in the wells and consequently the soil moisture is a way to reduce the negative effects of dry spells. Storing water underground presents several other advantages such as: reducing cost of exploitation (no need to dig deep wells), reducing maintenance, reducing waterborne diseases, enhancing water quality, conserving the land above the dam and reducing desertification (Onder and Yilmaz 2005).

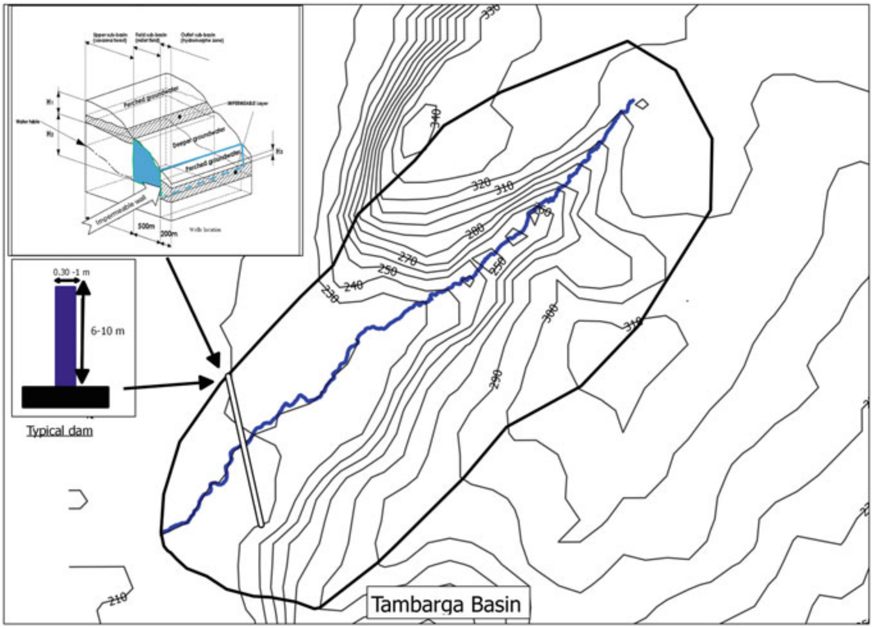

Fig. 8.9 Buried dam location

8.4 Conclusion

In the basin of Tambarga the major portion of runoff is generated by direct precipitation. The groundwater is disconnected between three areas of the basin: two shallow perched water tables (upper and bottom basin) and one deeper groundwater in the agriculture. The complete river baseflow is controlled by groundwater. The seasonal pattern of evaporation allowed identification of two peaks of latent heat flux that correspond to the grass growing, tree foliage and crop heading.

The processes highlighted allowed us to implement a simple lumped hydrological model refined with understanding of land covers, watertable distribution, evaporation and streamflow patterns. The model is still in development, but the preliminary results are promising, as the model is able to simulate the complex runoff behavior.

The amount of water stored in the groundwater implies that irrigation is a way to sustainably insure the agricultural productivity for Tambarga's local people. Irrigation scenario tests show that using buried dams and deeper wells for irrigation are alternatives for better agricultural production. The groundwater storage management appears to be a sustainable way to store water for livelihood, crops and plants at Tambarga. Future research can explore the type and method of irrigation as well as the long-term sustainability.

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Chapter 9
Rural Cold Storage as a Post-Harvest Technology System for Marginalized Agro-Based Communities in Developing Countries

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Abstract The goal of this paper is to provide the framework for the implementation of sustainable Rural Cold Storage (RCS) systems for farm produce in agro-based rural communities in developing countries. RCS, a post–harvest technology system for farm produce, is an appropriate technology for marginalized rural communities in developing countries that helps in prolonging the lifespan and freshness of perishable fresh farm produce (like leafy vegetables) at a minimal investment, especially for rural communities where electricity is lacking. The RCS system initially analyzed on the basis of thermodynamics principles by the research group has been constructed and tested with the involvement of the local farmers in selected rural communities in Nepal; the land of Mt. Everest. The preliminary data obtained is used to modify the design of zero-energy cool chambers and construction of RCS systems for implementation in agro-based rural communities in developing countries. RCS is an innovative sustainable system that enhances direct marketing by indigenous farmers in developing countries and inherently provides jobs for indigenous farmers, especially for women, therefore alleviating poverty in these rural communities. RCS is virtually a zero-energy technology that minimizes global warming and addresses issues. The RCS is built with local materials such as jute, bricks, sand, water, clay, straw, and bamboo, and

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it is operated at the cost of two buckets of water per day. The RCS can be constructed at a total cost of maximum US$120–$130 for 200–300 kg of farm produce.

9.1 Introduction

Agricultural development is a key to promote economic growth and sustainable poverty reduction for most livelihoods in developing countries (World Bank 2007; OECD 2006). This paper develops the framework and instruments for the implementation of Rural Cold Storage (RCS) systems for marginalized agro-based rural communities in developing countries. The RCS system is an innovative sustainable system that addresses the storage issues of farm produce of indigenous farmers in agro-based rural communities where electricity is lacking and also increases the economic returns for the farmers from their stored agro-produce by promoting the concept of direct selling (USAID 2011), thus minimizing the role of local vendors or middlemen (Bingen et al. 2003). In rural communities where electricity is lacking, the implementation of electricity-based storage systems like refrigerators and cold stores for fresh farm produce is unachievable. Moreover, the inefficiency of the agro-trade in Nepal (NPC 2011; MDD 2001; USAID 2011) brought about by several factors, such as lowreturns (Ellis 1992), small land plots, low levels of appropriate technology, a lack of access to credit, and weak supply chains (NPC 2011), has led to an accountable role for vendors/middlemen (Bingen et al. 2003) who have gaineda monopoly and caused an unreasonable price escalation of agro-produce (Carrasco and Mukhopadhyay 2012; Pokhrel and Thapa 2007; Shrestha and Shrestha 2000; Thapa et al. 1995) up to 40–50 % (ABPMDD 2010; Prabin 2012) of the original prices in Nepal, leading to long-lasting and deep socio-economic consequences (Carrasco and Mukhopadhyay 2012; UNESCAP 2012). Agro-based rural communities are faced with the challenges of preventing a heavy loss of their farm produce and adopting appropriate post-harvest technologies (Kitinoja 2010). The implementation of naturally based post-harvest storage systems is almost the only resort for such rural communities. Interactions and collaborations have initially been piloted with the local farmers in Nepal to implement the RCS system. Construction of a pilot RCS at a total maximum cost of US$120–$130 for 200–300 kg of farm produce has been implemented in some rural communities in Nepal as a case study for dissemination in agro-based rural communities in developing countries.

The RCS is virtually a zero-energy technology and is constructed with locally available materials, such as jute, bricks, sand, water, clay, straw, and bamboo, and can be operated at the cost of two buckets (30–40 l) of water per day. The RCS can be constructed by local indigenous farmers after initial training. The implementation of the RCS in some selected agro-based rural communities implicated the local farmers both in the construction and operation phases. The RCS technology seems to be appropriate for these agro-based communities. The local farmers where an RCS has been implemented seem to be happy that their fresh farm produce can be stored for some days without rotting and later transported to the local markets in the cities. The farmers who initially took part in the first implementation of the RCS are now being trained to extend the technology to neighboring agro-based communities. The preliminary data obtained from RCS is used to modify and advance the design and construction of the RCS system that would be used by farmers and others to prolong the lifespan and freshness of perishable fresh farm produce (like leafy vegetables) and enjoy the associated benefits.

The RCS, a sustainable post–harvest technology system, addresses fresh farm produce storage issues in agro-based communities. The issue of fresh farm produce rotting because of insufficient and inefficient storage systems is addressed by the RCS, which also provides food security for both the beneficiaries and the general public. In addition, the RCS will provide jobs (and job security) for indigenous farmers, especially women, there by alleviating poverty in these agro-based rural communities. RCS is an energy-independent technology based on the principles of evaporative cooling that minimizes global warming and addresses climate change issues (Jain and Tiwari 2002). The on-field data measurement and analysis for the RCS demonstrate an innovative sustainable system that addresses the storage issues of farm produce of the indigenous farmers where the RCS was implemented. The challenges were addressed by exploiting various natural phenomena in an innovative and creative way, with minimum cost and considerable beneficial outcomes to ensure *sustainable solutions* (Bos et al. 2007; Vorley 2002). In this regard, the RCS is introduced by targeting the poor farmers to close the agricultural development gap in rural communities in developing countries.

The implementation of the RCS in the selected rural communities in Nepal was done in collaboration with government workers in the Department of Water Supply and Sewerage, Government of Nepal; research engineers seeking their doctorate degrees in North Carolina Agricultural and Technical State University (NCATSU), United States;and the Institute of Engineering (IOE) at Tribhuvan University in Nepal; senior scientists of the Food Research Division, National Agriculture Research Centre (NARC) in Nepal; and the local farmers for whom the RCS was initially implemented. Collaborations and partnerships are now being developed with interest groups in Ghana (Kumasi) to disseminate the RCS technology in developing countries, particularly in agro-based communities. Faculty members at Kwame Nkrumah University of Science and Technology, Ghana, have agreed to continue research on upgrading the performance of RCS by providing project topics to their students for system performance studies. The interest groups are in the stage of preparing workshops and seminars to train local farmers on the benefits of the RCS system so that it can easily be integrated as a sufficient and efficient post-harvest storage system in such communities. The following section presents the initial background studies for the implementation of RCS with Nepal as the country for case studies.

9.2 Implementation of RCS with Nepal as the Country for Case Studies

The agro-based economy of Nepal contributes about 35.66 % to its gross domestic product (GDP) (NPC 2011) and more than 74 % employment to economically active labor force (Ministry of Finance 2011), particularly from the agriculture sector only, where the majority (83 %) of the population (CBS 2011a) comes from the rural area. Small fragmented subsistence farming is its salient feature, having over 53 % of farmers each operating on less than 0.5 hectare (ha) of land and over 4 % on more than 2.0 ha of land (CBS 2011b). The reports showing post-harvest losses of agro-produce in Nepal ranging generally from 25 to 50 % (Kitinoja 2010; Prabin 2012; USAID 2011) reveal a deteriorating economic status of the rural peasants, a majority of whom (65 % of small farmers) are living below the poverty line (ADB 2010). The overall performance of the country in the area of socio-economic development is largely influenced by the development of the rural area. So there is a need to introduce feasible appropriate technologies that address the agro-business challenges in rural areas and minimize the development gap. The RCS, due to its easy installation mechanism (requiring less time and physical labor), is more suitable for women to use, which in turn increases their participation in producers' groups, and related marketing activities then have a better chance of enhancing food sufficiency and generating higher returns at the household level (Allendorf 2007; FAO 2011; Thapa 2012; World Bank 2011).

Several indigenous technologies developed by ancient farmers, such as bamboo cooler, charcoal cooler, and in recent days, cellar technology (Kitinoja 2010; Practical Action 2008), still exist today at the village level. However, these technologies face several difficulties regarding their installation, operation, maintenance, and commercialization criteria. In urban areas, even costly electrically operated cold stores are ineffective due to the frequent power-cuts (up to 14 h a day in the dry season) Nepal Electricity Authority (NEA) 2011, whereas in poverty-stricken rural areas, a reliable and accessible rural electrification has long been a great challenge. Besides this issue, food security, post–harvest losses, and longer availability of farm products in an affordable manner are among the major factors affecting agro-business in rural Nepal.

After extensive interaction with stakeholders-farmers, middlemen, customers, and government bodies-it has been identified that there is a strong need for an affordable means of preserving perishable food stuffs for longer periods (Mogaji and Fapetu 2011). Considering the current poor economic status of the small-scale rural farmers and high power outage situation of their villages, meeting this need is almost impossible. An immediate alternative is to consider the use of cheap and renewable energy technology, for example, the RCS system. It is a zero-emission or simply a virtually zero-fuel technology that utilizes the natural potential energies of solar radiation and the breezes for its functions and preserves the agro-produce for one to two weeks without any considerable Physiological Loss in Weight (PLW). The RCS methodology is presented in the following section.

9.3 Scientific Questions

To develop an effective and efficient system, the following scientific questions need to be addressed:

1. What is the functionality of the construction materials for the intended application?
2. Should the entire storage space be airtight or is certain airflow to be maintained?
3. What is the internal temperature distribution in the storage space?
4. What are the system's input requirements and extent of attainable cooling and humidification?
5. What is the optimum wall thickness for the best cooling mechanism, considering the mutual effects all of the three thermodynamic phenomena of evaporative cooling, hot radiation inflow, and adiabatic humidification?
6. How should the system be adjusted to recycle water and vapor in the system?

9.3.1 Methodology

This study seeks to develop an RCS technology that harnesses renewable energy to preserve a quantity of foodstuffs. To achieve this goal, a number of steps were taken:

1. Designing and testing a prototype of the RCS system.
2. Investigating environmental and design factors and their effects on the functionality of the system.
3. Establishing operational parameters of the RCS system for optimal application.
4. Implementing the final design model in selected agro-based rural communities in villages of Nepal.

9.3.2 Design Considerations and Operation of RCS

The RCS system was designed by the research group and is shown schematically in Fig. 9.1.

The RCS consists of a storage chamber $(1.5 \times 1.2 \times 1)$ m^3 where heat is extracted and moisture is increased. This chamber is bounded by four brick walls from the inner side with an intermediate (sandwiched) layer of sand (7.62 cm thick) held in place by either jute or a net from outside. A perforated pipe (1.27 cm diameter) is placed longitudinally over the sand layer between the inner brick wall and outer jute layer. A thin permeable cloth is wrapped around the brick layer to prevent the outflow of sand mass through interstices of brick wall. A 2.0 mm thick

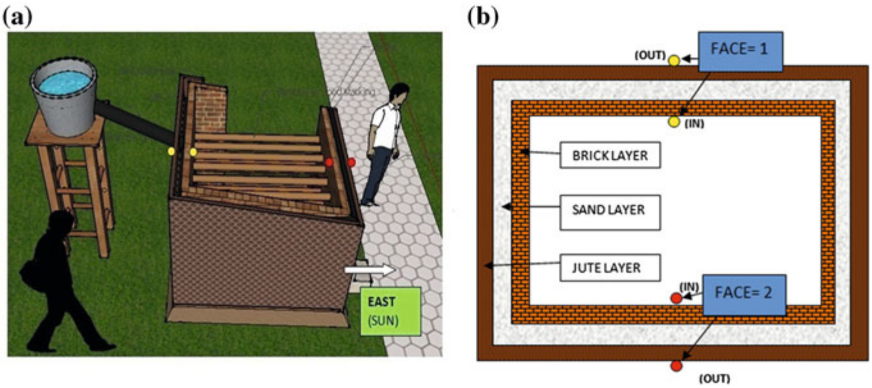

Fig. 9.1 RCS design configurations (schematics), (a) Conceptual diagram of jute model, (b) Schematic diagram of jute model

jute layer is vertically attached on each inner wall. The agro-produce is packed in small quantities inside perforated plastic bags to maintain a good air flow and prevent any unwanted contamination from the outer environment. The storage chamber is designed to accommodate nine to 12 commercial plastic baskets or 200–300 kg of agro-produce for duration of three to15 days depending upon the items. The entire system is covered with a lid made of dried clay and wet jute on top in an inclined position and is kept in shade under a straw canopy. An optional small fan was kept at the bottom ventilation for air circulation.

The supplied water trickles continuously out of the perforated pipe lying over the sand and keeps the sand constantly wet. Thus, the water is retained in the sand and percolates deeper until it reaches the internal brick boundary layer. After more water infiltrates the bricks' pores, the water reaches the surface of the outer boundary of the brick layer. Thus, the water wets both the adjacent brick and jute layers. At this point, the accumulated water on the exposed faces of both layers evaporates due to the latent heat of vaporization from the surface and consequently lowers the jute and brick temperatures as per the principle of evaporative cooling. Simultaneously, adiabatic humidification also proceeds inside the storage chamber further lowering the temperature inside the system. Figure 9.2 shows the on-field implementation of RCS.

9.3.3 Temperature Modeling

Prior to the physical construction and implementation of the RCS system, a model was developed in MATLAB[1] (on the basis of literature by Herrero 2009; Incropera and Dewitt 2001; Pires et al. 2011; Wei Chen 2011; Vasiliev and Maiorov 1979)

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1 Technical computing software.

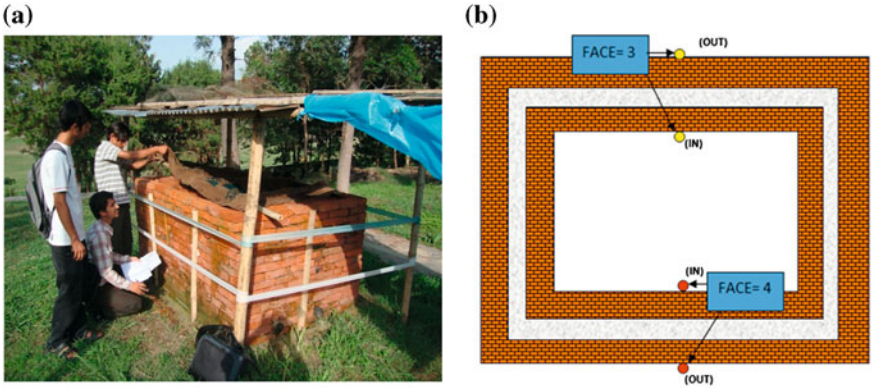

Fig. 9.2 RCS design implementation, (a) Picture of brick model, (b) Schematic diagram of brick model

using correlations of evaporative cooling of a wetting agent (water) to estimate the possible temperature regimes. Figure 9.3 shows the initial analytical results for the underlying problem. For example, at an ambient temperature of 22.6 °C, we estimate the temperature of the chamber to be 19.02 °C. This also means that at a 22.6 °C ambient temperature, a 3.58 °C temperature drop is obtained. A set of ambient conditions of the area where the RCS project is to be implemented are used in solving the above problem. Selection of constants like the Lewis parameter (n) is based on the materials' (water and sand) properties. The output of the MATLAB simulation is used as an insight in estimating possible temperature regimes for the on-field RCS implementation. Figure 9.3 shows the results.

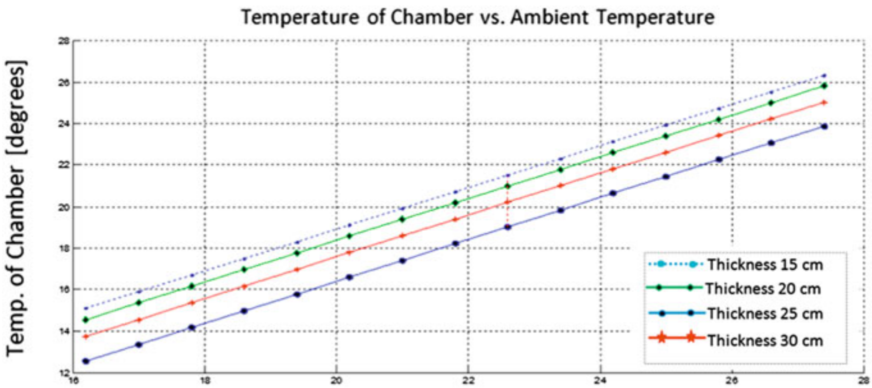

Fig. 9.3 Simulation results of temperature modeling

9.4 RCS Implementation in the Field

Implementation of pilot RCS jute model was done by a local marginalized famer's cooperative named *Srijana Jana Kalyan Samudayik Sanstha* in Masardada, Bhimad, Tanahun of Nepal, with the technical support of the researcher's group and a government agency, the Alternative Energy Promotion Center (AEPC), Khumaltar, Nepal. The Mothers' Group (*Aama–samuha*) of neighboring agro-based communities and Sisnehari Village are showing keen interest in extending RCS in their villages.

9.4.1 Construction

Two configurations of the RCS were designed and constructed using indigenous materials as follows:

1. Lay bottom brick/stone soling masonry layer.
2. Erect two brick walls with a cavity gap in between. However, the outer layer is optional and could be replaced by a jute layer externally bounded by a chicken wire mesh/net. Bamboo reinforcement is provided on both sides.
3. Provide two circular ventilations (7.62 cm diameter) on each side of opposite shorter walls at top (with 2.54 cm free board) and bottom (2.54 cm above floor level). An optional small fan is fitted.
4. Fill the cavity gap with the sand.
5. Lay the perforated pipe longitudinally over the sand layer in the cavity.
6. Cover the cold storage with an air-tight lid made of dried clay and wet jute on top in an inclined position.
7. Cover the entire cold storage structure with a canopy to provide shade.

During operation at the premises of IOE, Pulchowk Campus, and Masardada Village at Bhimad of Tanahun District of Nepal, it was observed that the RCS can function using only two buckets (30–40 l) of water per day.

9.4.2 Data Acquisition and Analysis

Operational parameters (temperature, moisture, and relative humidity) of the system were observed and collected over a period of time in between mid-October 2009 and the end of October 2010 that included both summer and winter seasons. Statistical analysis was performed on the field data recorded from the prototype tests of both the jute and brick models of the RCS system. The results show that the jute design provided better cooling than the brick design. The average relative humidity (RH) of the jute model was observed to be higher than the brick model.

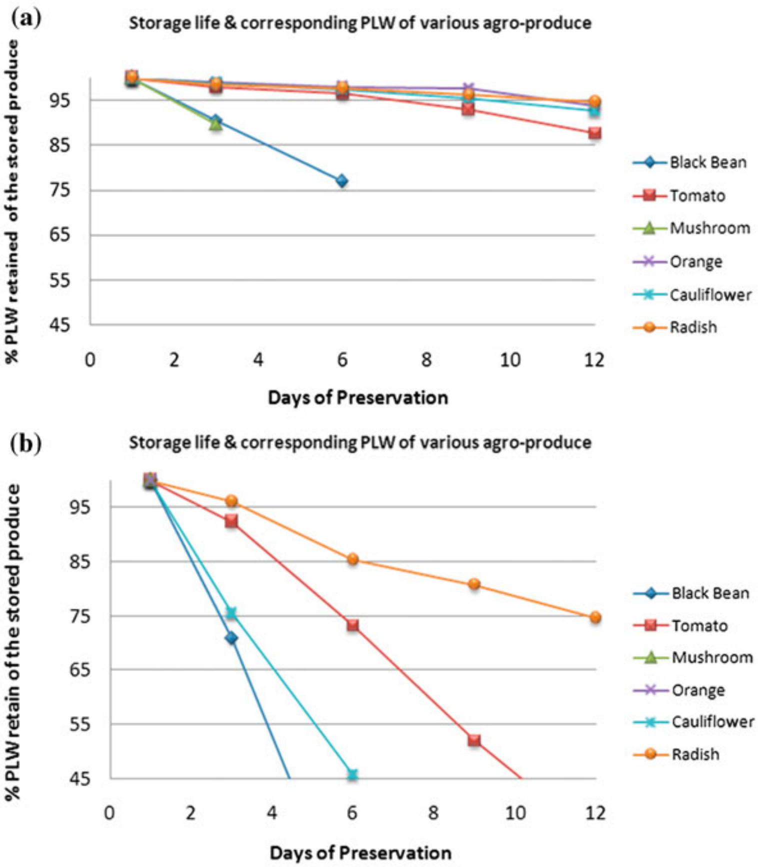

Fig. 9.4 Agro-produce storage performance of RCS in winter season (2009), (a) Preservation done inside RCS, (b) Preservation done inside a cool room

However, the brick design provided better moisture retention than the jute design. The results of the analysis reveal that the temperature difference between ambient and within storage space in hot weather was observed to be 10–15 °C and around 5–6 °C in cold weather, and can store the farm produce for three to 15 days depending on the type. Figure 9.4 shows the results of the performance of RCS.

9.4.3 Vegetable Species Preservation Performance

The data obtained from the implemented RCS is plotted in terms of the performance of the storage system. The performance of the system is measured in terms of the storage life and retention of the freshness of the farm produce. Figure 9.4 and Fig. 9.5 show the results for winter and summer seasons respectively.

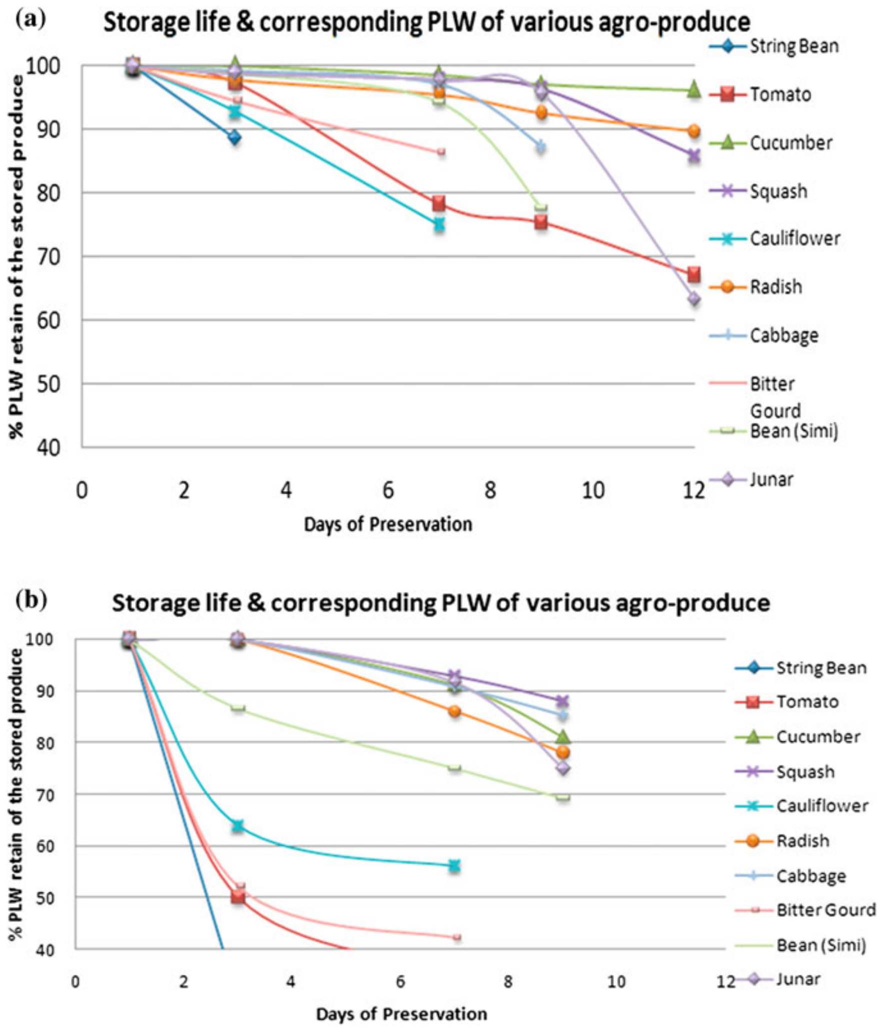

Fig. 9.5 Agro-produce storage performance of RCS, summer season (2010), (a) Preservation done inside RCS, (b) Preservation done inside a cool room

The best preservation effect for the agro-produce inside the RCS during winter season was observed, in descending order, for radishes, oranges, cauliflower, tomatoes, black beans, and mushrooms (only 3 days), where as during the summer season, the order was cucumber, junar, radishes, gourd bean, bitter gourd, tomatoes, cauliflower, black beans.

Table 9.1 Cost for a single RCS system

Particulars	Jute model	Brick model
Construction cost (materials and facilities)	US$ 70–$80	US$ 120–$130
Labor cost for construction of RCS system	US$ 80	US$ 80
Operation and maintenance cost (every 2 years)	US$ 55	US$ 45
Salvage value recovery	90 % of Investment	95 % of Investment

9.4.4 Cost Analysis

The cost for the implementation of single unit of RCS in selected communities in Nepal is presented in Table 9.1.

The cost of the RCS system is based on the size that can accommodate about 200300 kg of fresh farm produce andproves to be much cheaper than other models of zero-energy cool chambers (Kitinoja and Thompson 2010). Preliminary cost analysis has indicated that the total cost of the RCS system can be recovered within 12 years.

The RCS can prolong the lifespan of different commodities from three to 15 days—much longer than they can be stored outside. From a preliminary survey of commodity price depreciation at Kalimati Fruits and Vegetable Market-Kathmandu, it was observed that by taking a reference of 25 % of PLW for each commodity, a relative 20 % average higher return in commodity price value can be achieved compared to their saleable price at 25 % of PLW-time period for the items kept outside the system. Similarly, corresponding to their maximum storage life period up to 25 % of PLW within the RCS, a relative 80–85 % of average higher return can be achieved for different commodities compared to their saleable price at the time outside the RCS.

Preliminary analysis of storage life and return value of commodities has indicated that the RCS promotes the concept of direct marketing and assures higher returns from commodities by providing enough time for small farmers to carry their agro-produce themselves for selling in the local markets at a good price, keeping the consumer price constant and thus helping in minimizing the role of local vendors in the supply chain. Consequently, this will not only help in controlling unreasonable price hikes occurring in the Nepalese market, it will also will help to transfer a certain weightage of commodity price in the supply chain from vendors' to farmers' portions without escalating the consumer prices.

9.4.5 Strategic Project Implementation Plan

The implementation of the RCS in agro-based rural communities in developing countries is simplistically strategized in the following steps:

1. Workshops and seminars to be organized for local farmers on the construction, implementation, and operation of the RCS system.
2. Promotion of RCS via "group marketing model"2[2] through groups/cooperatives of local farmers.
3. Involvement of government and private agencies to disseminate RCS technology in developing countries.
4. Farmers are trained to extend the RCS technology to their own communities and neighboring agro-based communities.
5. Periodic monitoring and performance evaluation of on-field RCS systems.

9.5 Conclusions

The on-field data measurement and analysis for the RCS system demonstrate an innovative sustainable system that addresses the storage issues and higher returns of fresh farm produce of indigenous farmers in rural communities in developing countries. The cost comparison shows the jute model to be 40 % cheaper relative to the brick model. The challenges of storing fresh farm produce by poor farmers in rural communities were addressed by exploiting various natural phenomena in an innovative and creative way with the minimum cost and considerable beneficial outcomes to ensure sustainable solutions. In this regard, the RCS is introduced targeting the poor farmers in developing countries to close the agricultural development gap. The RCS is an indigenous cold storage technology for food preservation and does not require any fuel or to operate. RCS is a potential energy-independent technology that is constructed with locally available materials (jute, bricks, sand, bamboo, jute, and water). Successful implementation of the RCS system in agro-based rural communities will help to provide jobs (and job security) for rural farmers who have problems for storing their fresh farm produce. In addition, beneficiary farmers will be assured of good prices for their farm produce as the RCS system will retain the freshness of their farm produce and allow time for direct selling in the market.

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[2] As described in (USAID 2011). *Value Chain/Market Analysis of the Off-Season Vegetable Sub-Sector in Nepal*. Kathmandu, Nepal: USAID.

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Chapter 10
Iron-Catalyzed Low Cost Solar Activated Process for Drinking Water Disinfection in Colombian Rural Areas

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Abstract Solar Water Disinfection (SODIS) is enhanced by the addition of small amounts of H_2O_2/iron salts under solar irradiation. The disinfecting efficiency of the photo-assisted systems: $Fe^{2+/3+}/h\nu$ and $Fe^{2+}/H_2O_2/h\nu$ were observed at laboratory scale. At field scale using a 20-L Compound Parabolic Collector (CPC) reactor to treat river water (Pance River, in Cali, Colombia), the total bacterial inactivation was attained within 49 kJ/L of accumulated energy. Borosilicate and polyethylene terephthalate (PET) bottles used for *Escherichia coli* (*E. coli*) inactivation under simulated solar light showed similar inactivation kinetics leading to 8-$\log_{10}$ reduction of the *E. coli* concentration within 4 h. In presence of $Fe^{2+}/H_2O_2/h\nu$, a dramatic enhancement of bacterial inactivation rate was observed leading to 9-$\log_{10}$ bacterial reduction within 2 h for PET and borosilicate bottles. PET bottles were also evaluated under natural sunlight and complete *E. coli* inactivation was reached at pH 6.3 with 50 kJ/L of accumulated energy. After the photocatalytic treatment, no bacterial re-growth was observed within the next 24 h of dark storage. These results exhibit the potential of the near-neutral photo-Fenton process for enhancing SODIS. Furthermore, PET bottles appear to be a promising option for application at the household-level for the rural population of developing countries, receiving a relatively high daylight sun irradiation.

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10.1 Introduction

Harmful microorganisms are a major problem in drinking water; especially in developing countries where water treatment is often inadequate or non-existent. Indeed, the presence of pathogenic microorganisms leads to severe diseases. In Latin America, 8% of total deaths of children aged five years or less is caused by acute diarrheic disease (Craun 1996). In Colombia, the Ministry of Health (Ministerio de la Salud y Prevención 1998) reports that diseases caused by water transmitted infectious agents affect 4.5% of the total population, since a significant part of the inhabitants of Colombian rural areas has no access to acceptable drinking water. Disinfection is done by chlorination. Unfortunately chlorination has two limitations: (1) in presence of Natural Organic Matter (NOM), chlorination leads to the formation of disinfection by-products (DBPs) such as trihalometanes (THMs) (Bekbolet and Balcioglu 1996). The concentration of such compounds depends on both the level of NOM in water and the dosing of chlorine; as a consequence, in communities where the disinfection process is not carried out in optimal conditions, the chemical risk due to generation of DBPs is high, and (2) the restriction of chlorine supply, especially in isolated regions with economic and social limitations.

A study, carried out in the Municipal Public Health Department of the city of Cali in Valle del Cauca, Colombia reported that only 14% of the rural population has access to safe drinking water. The remaining 86% is unsafe water (Cedetes, Secretaria de Salud Pública Municipal de Cali 2007). In this sense, there is an urgent need for innovative low cost and safe drinking water treatment, requiring a small energy input, using local human resources and low maintenance cost.

Solid Water Disinfection (SODIS) is a simple, low-cost treatment convenient for sunny regions, such as Colombia. The SODIS disinfection is synergistic using oxidative species generated by the solar radiation and the temperature rise (Acra et al. 1980). This treatment is strongly temperature dependent, and treated volume is limited to 1–2 L. Also bacterial re-growth is sometimes observed during water cooling and storing.

Recently, the photo-Fenton process $\left(Fe^{2+3+}/H_2O_2/h\nu\right)$ was observed to speed-up the solar photo-inactivation of *E. coli* at neutral pH (Rincón and Pulgarín 2007a, b, 2006; Ndounla et al. 2013). Fenton's reagent action is based on the reaction of H_2O_2 with $Fe^{2+/3+}$, producing hydroxyl radicals ($^{\bullet}OH$) and other highly oxidative radicals in solution. The homogeneous Fenton (Eq. 10.1) and photo-Fenton reactions (see Eqs. 10.1, 10.2) have been used in the degradation of organic pollutants (Pulgarín and Kiwi 1996) and more recently for bacterial inactivation (Spuhler et al. 2010).

$$Fe^{2+} + H_2O_2 \quad \rightarrow \quad Fe^{3+} + HO^{-} +^{\bullet} OH \tag{10.1}$$

$$Fe(OH)^{2+} + h\nu \quad \rightarrow \quad Fe^{2+} +^{\bullet} OH + H^{+} \tag{10.2}$$

$$\left[R - COO^{-} - Fe^{3+}\right]^{2+} + h\nu \rightarrow Fe^{2+} + CO_2 + R^{\bullet} \tag{10.3}$$

In the photo-Fenton process (Eq. 10.2) the Fe^{3+}-hydroxy complexes undergo photo-reduction under Ultraviolet A (UV-A) and visible radiation regenerating Fe^{2+} via ligand-to-metal charge transfer (LMCT) lead to additional production of $^{\bullet}OH$ (Ciesla et al. 2004). In waters containing Dissolved Organic Matter (DOM) Fe^{3+} may complex with certain of these organic compounds, especially with those acting as ligands. The formation of Fe^{3+}-organo complexes are stable at environmental pH (6–7), circumventing the need for low pH of the traditional photo-Fenton process. The photolysis of these Fe^{3+}-organo complexes, which have generally a high molar absorption coefficient in UV-A and visible light leads to the regeneration of Fe^{2+} and the formation of a ligand radical (Eq. 10.3) (Feng and Nansheng 2000). Both, Fe^{2+} and organic radicals react with O_2 leading to the formation of Reactive Oxygen Species (ROS) $\left(O_2^{\bullet -}, ^{\bullet}OH, H_2O_2\right)$ (Faust and Zepp 1993), Fe^{2+} also directly reacts with H_2O_2 via the Haber–Weiss reaction (Eq. 10.1), leading to the regeneration of Fe^{3+} and the production of $^{\bullet}OH$.

Thus, the application of the photo-Fenton process at neutral pH to solar drinking water treatment is an innovative way to attain water disinfection. The process allows not only to kill pathogenic microorganism but also to treat, with limited risk of bacterial re-growth, large water volumes compared to the classical SODIS system. The purpose of this study is to enhance the SODIS treatment by adding low quantities of hydrogen peroxide in presence of iron salts to produce, under solar light, highly reactive hydroxyl radicals. We address: (a) bacterial inactivation and the durability of the disinfection (post-irradiation events) under simulated solar light by three photo-assisted systems: (i) light induced disinfection ($h\nu$), (ii) $Fe^{2+/3+}/h\nu$ and (iii) $Fe^{2+}/H_2O_2/h\nu$ systems. (b) Bacterial inactivation in surface drinking water sources (Pance River, in Cali, Colombia) by near-neutral photo-Fenton process, using low concentrations of Fe^{3+} and H_2O_2 at "natural" pH in a CPC solar photoreactor. (c) Comparison of borosilicate and PET bottles, as near-neutral photo-Fenton reactors for *E. coli* inactivation under simulated solar irradiation and natural sunlight.

10.2 Materials and Methods

10.2.1 Reagents

The near-neutral photo-Fenton process was carried out using Ferrous sulfate heptahydrate ($FeSO_4.7H_2O$) (Riedel-de Haën 99–103.4%) or Iron chloride ($FeCl_3.6H_2O$) (Buchs, Switzerland) and hydrogen peroxide (H_2O_2) 30% w/v (Riedel de Haën). All solutions were prepared in Milli-Q water. Milli-Q water refers to ultrapure laboratory grade water that has been filtered and purified by reverse osmosis.

10.2.2 Analytical Methods

H_2O_2 concentration was monitored using analytical strips Merkoquant (Merk). Experiments were carried out at "natural" pH and were monitored on a Thermo Scientific pH meter. Total iron content was measured by atomic absorption on a Perkin Elmer Analyst 100 instrument.

10.2.3 Microbiological Methods

The *E. coli* strain K –12 (MG1655) preserved at low temperature and glycerol was reactivated in petri dishes on Plate Count Agar (PCA) (Merck, Germany) by the streak plate technique and incubated at 37 °C for 24 h. To prepare the bacterial pellet for the photo-inactivation experiments, one colony was picked from the pre-cultures and loop-inoculated into a 100 mL of CASE Bouillon broth (Merck). The flask was then incubated at 37 °C for 15 h to obtain a steady state bacterial culture. Cells were harvested by centrifugation (10 min at 3000 X g RCF and 4 °C). The bacterial pellet was re-suspended and washed in 0.85% NaCl for 10 min in the centrifuge (twice). This procedure leads to a bacterial suspension of approximately 10^9 Colony Forming Units per milliliter (CFU/mL).

10.2.4 Photo-Inactivation Experiments

10.2.4.1 Laboratory Experiments Using a Solar Simulator (Suntest)

Laboratory scale experiments were conducted in a solar simulator (Suntest) (CPS Suntest System Heraeus Noblelight, Hanau, Germany). The Suntest system contained a basic uncoated quartz glass light tube with a filter E and an infrared (IR) screen (simulation of solar global radiation outdoors daylight). The emitted radiation corresponds to 0.5% of total photons emitted at wavelengths <300 nm (UV-C and UV-B range). The spectrum at wavelengths >300 nm follows the natural solar spectrum.

Borosilicate reactors were 4 × 9 cm, 100 mL, contained the bacterial suspension in Milli-Q water (approximately 10^7-10^8 CFU/mL) and were placed in the dark at 25 °C under magnetic stirring in a solar simulator for at least 30 min. This allowed the bacteria to adapt to the new matrix and to allow the die-off and equilibration of the most stress sensitive species. The disinfecting efficiency of three photo-assisted systems were evaluated: (i) only light irradiation (hν), (ii) $Fe^{2+/3+}/h\nu$ (Fe 12 mg/L) and (iii) $Fe^{2+}/H_2O_2/h\nu$ (Fe 0.6 mg/L, H_2O_2 10 mg/L). The control experiment consisted of an *E. coli* suspension without reagents. Aliquots were taken during pre-set intervals and were diluted (10 % steps) and plated out on PCA. Plates were then incubated in an incubator (Heraeus Incubator B 5060 *EK*-CO_2, Heraeus Instruments, Hanau, Germany). After 24 h, CFU were counted manually.

10.2.4.2 Field Experiment Using a CPC Reactor

The field scale reactor used in drinking water disinfection under solar light is shown in Fig. 10.1b. The photo-reactor consists of borosilicate glass tubes, which are placed over reflective surface of anodized aluminum inclined to 3°, corresponding to the latitude of the location site. 20 L of water were circulated through the reactor at 18 L/min, leading to a recirculation tank connected to a centrifuge

Fig. 10.1 Different solar water disinfection systems: (a) Solar Simulator (Suntest CPS); (b) CPC reactor exposed to natural sunlight, used at the University of Valle-Colombia; (c) borosilicate and PET bottles placed on an aluminum platform

pump. The illuminated volume photo-reactor was 8 L. Solar UV radiation was determined during the experiment by means of a global UV radiometer (ACADUS S2004 with an LS-3300 controller) mounted at the same angle as the CPC reactor (3°, Cali, Colombia). This allows the comparison of the energy reaching the surface at the same position with regard to sunlight irradiation. The accumulated incident light energy on the photo-reactor per unit volume ($Qu\nu_{,n}$) was calculated by the application of Eq. 10.4 (Gernjak et al. 2003).

$$Qu\nu_{,n} = Qu\nu_{,n-1} + \Delta t_n UV_{G,n}[A_{CPC}/V_{TOT}], \Delta t_n = t_n = t_{n-1} \tag{10.4}$$

where t_n is the experimental time at which the sample was taken, V_{TOT} the volume of reactor (8 L), A_{CPC} the illuminated surface of collector (0.905 m^2), $UV_{G,n}$the average, UV_G (UV global radiation) during Δt_n, and $Qu\nu_{,n}$ is the accumulated energy (per unit of volume, kJ/L).

The surface water was obtained from a natural source (Pance River, in Cali, Colombia). This river is a water supply for some communities (i.e., ″El Retiro″), which use Slow Sand Filtration (SSF) as pre-treatment system. Samples were taken after SSF and spiked with *E. coli* (10^7 CFU/mL). Thereafter, the bacterial suspension was exposed to natural sunlight irradiation in the presence or absence of Fe^{3+} (0.6 mg/L) and H_2O_2 (10 mg/L), without pH modification (initial pH 6.5–7.0) and under sunlight in Cali, Colombia using a CPC reactor. Bacterial inactivation was assessed at different times. After serial dilutions, samples were plated out on PCA, incubated for 24 h at 37 °C. CFU were then counted manually.

10.2.4.3 Borosilicate and PET Bottles on *E. coli* Inactivation Using a Solar Simulator and Natural Sunlight

Borosilicate and commercial bottles of PET of 500 mL were used as reactors. The bacterial suspension (10^8 CFU/100 mL) was exposed to the simulated solar irradiation (Fig. 10.1a) and sunlight irradiation (Fig. 10.1c) in the presence or absence of Fe^{2+} (0.3 mg/L) and H_2O_2 (20 mg/L). The pH was adjusted at 6.0 with 0.1 M NaOH solution. Each photo-catalytic experiment was performed in duplicate. For the determination of CFU/mL in water, Membrane Filtration (MF) method was used. 5 mL of the samples of the treated water were collected at regular time intervals and were diluted into 45 mL of water containing peptone (Merck) and sodium chloride (9 g NaCl and 1 g peptone for 1 L). Aliquots were diluted in 10% steps. The solution was then filtered, and the filter of 0.45 μm (Sartorius Stedim) was plated out on PCA. After 18–24 h, CFU were counted manually.

10.2.5 Post-Irradiation Events

At the end of the irradiation phase, bacteria re-growth was determined by leaving the last three samples in the dark at room temperature for 24 h before the CFU counting. The samples were kept in the dark without removing the remaining H_2O_2 that ensures residual disinfection.

10.3 Results

10.3.1 *E. coli* Inactivation in Milli-Q Water at Laboratory Scale Using a Solar Simulator

Total inactivation of *E. coli* was not observed in Milli-Q water until the fifth hour, under light irradiation alone. However, a 5-$\log_{10}$ *E. coli* reduction was reached as shown in Fig. 10.2, system (I). Temperatures during the runs did not exceed 38 °C. To further evaluate the effect of simulated solar light, the dark repair of *E. coli* after this treatment was investigated. As shown in Fig. 10.2, in the dark, bacterial reactivation occurs for bacterial solution treated with simulated solar light (system I). These results show that simulated solar light induced damage in the deoxyribonucleic acid (DNA), which bacteria can self-repair.

Figure 10.2, systems (II, III) shows that bacterial inactivation by the simulated solar light was enhanced by the addition of Fe^{2+} and Fe^{3+} (12 mg/L). A decrease of 7-$\log_{10}$ *E. coli* reduction was observed during 5 h of exposure. The experiments

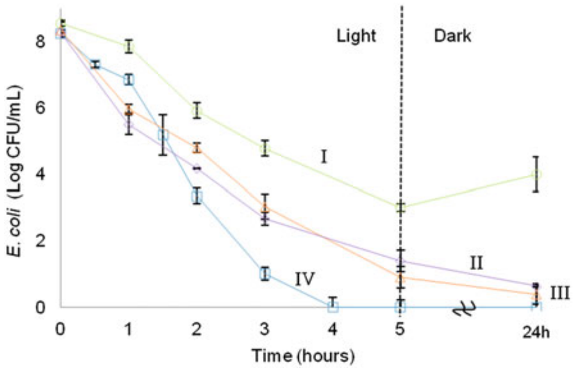

Fig. 10.2 *E. coli* inactivation (○) simulated solar light (I); (◇) Fe^{2+} under light (12 mg/L (dissolved iron 3.4 mg/L)) (II); (Δ) Fe^{3+} under light (12 mg/L (dissolved iron 2.1 mg/L)) (III); (□) near-neutral photo-Fenton Fe^{2+} (0.6 mg/L)/H_2O_2 (10 mg/L)/simulated solar light (IV). Simulated solar light intensity (520 W/m^2). Experiments were conducted in triplicate and standard error was found to be around 5%

were carried out at pH 5.4–5.8 and the dissolved total iron was 3.4 mg/L and 2.1 mg/L starting with ferrous sulfate and ferric chloride respectively. No re-growth in the dark was observed and the bacterial concentration continued decreasing for 24 h after stopping illumination, when $Fe^{2+/3+}$ was added. The interesting point in these systems is that no addition of hydrogen peroxide is needed.

Complete inactivation of *E. coli* was achieved for 10^8 UFC/mL after 4 h of simulated solar light in the presence of Fe^{2+}/H_2O_2 (Fig. 10.2, system IV). At the end of the experiments, the residual concentration of H_2O_2 was 2 mg/L. After stopping illumination, no bacterial recovery was observed for 24 h in the dark, which is indicative of the strong bactericidal effect of this treatment.

10.3.2 E. coli Inactivation in Natural Water at Field Scale Using a CPC Reactor

In order to gain insight into field-scale efficiency of solar-driven near-neutral photo-Fenton, a solar CPC photo-reactor, able to treat up to 20 L of water was used. The experiments were carried out with natural water coming from Pance River, in Cali, Colombia. Figure 10.3a, system (II) shows that by the addition of 0.6 mg/L of Fe^{3+} and 10 mg/L of H_2O_2, *E. coli* was inactivated at near-neutral pH 6.8 applying an accumulated solar energy of 49 kJ/L. Two additional experiments were conducted under similar conditions to evaluate the reproducibility of results. Total bacterial inactivation was reached within a range of 41–49 kJ/L of accumulated energy. Control experiments confirmed that *E. coli* inactivation did not significantly occur only due to light irradiation (Fig. 10.3a, system I). The UV irradiance had an average value of 30 W/m^2 and very little modification of the water temperature (30–38 °C) was detected during the period of the run (Fig. 10.3b). After stopping illumination, no bacterial recovery was observed after 24 h in the dark for the photocatalytic treatment.

10.3.3 Comparison of Borosilicate and PET Bottles on E. coli Inactivation Using a Solar Simulator and Natural Sunlight

Bacterial reduction of 8-$\log_{10}$ was reached within 4 h for both borosilicate and PET bottles under simulated solar irradiation (Fig. 10.4a, systems I and II). Water temperature inside the batch reactor remained under 38 °C. From Fig. 10.4b, it is seen that PET has an absorption cut-off at about 330 nm, whereas for borosilicate, absorption starts at 300 nm. Despite this significant reduction in UV-A transparency, the final concentrations of bacteria in the PET bottles (system II) are

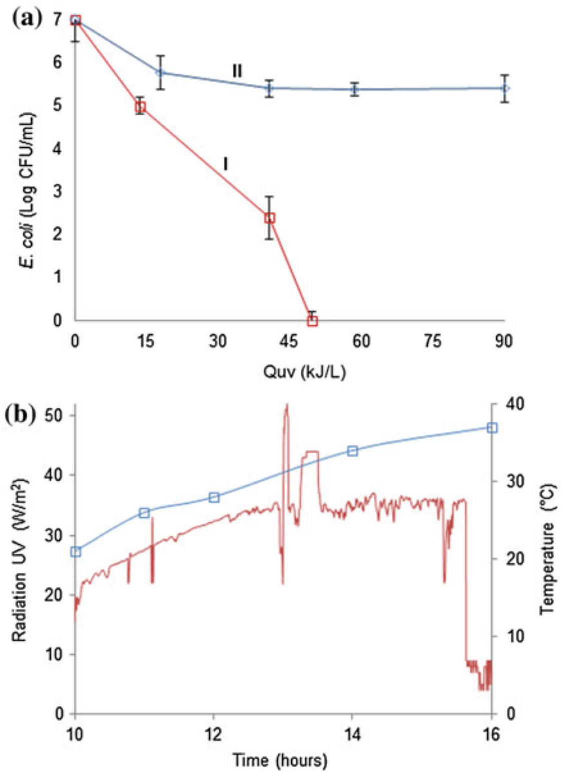

Fig. 10.3 (a) *E. coli* inactivation by sunlight in a CPC reactor. (☐) near-neutral photo-Fenton (Fe^{2+} 0.6 mg/L; H_2O_2 10 mg/L)/solar light, (I); (◇) solar light (SODIS Control) (II). Experiments were conducted in triplicate and standard error was found to be around 5%. (b) UV solar irradiance in Cali–Colombia during the experiment. Real time: from 10 until 16 h (*red line* in the figure). Temperature: 21-38 °C (*blue line* in the figure)

comparable with those in the borosilicate bottles (system I) under exposure to simulated solar irradiation. When Fe^{2+} 0.3 mg/L and 20 mg/L of H_2O_2 were added into PET and borosilicate bottles, a dramatic enhancement of bacterial inactivation rate was observed leading to 9-$\log_{10}$ bacterial reduction within two hours for borosilicate and PET bottles (Fig. 10.4a system (III and IV). No significant difference in inactivation kinetics was observed for both materials. The efficiency of PET bottles was also evaluated under natural sunlight. Fig. 10.5a shows that under solar light, using Fe^{2+} and H_2O_2, complete *E. coli* inactivation from 10^9 CFU/100 mL was reached at near neutral pH 6.3 with 50 kJ/L of accumulated energy. In the control experiments (SODIS), it was confirmed that *E. coli* inactivation needed more than 115 kJ/L of accumulated energy. The UV irradiance had an average value of ~35 W/m^2 during the experiment (Fig. 10.5b). This parameter must be taken into account, as the UV dose alone, is not always a suitable parameter to monitor the performance of solar disinfection systems. Minimal irradiance (Rincón and Pulgarín 2004) and dose (Sichel et al. 2007) are required for efficient solar disinfection. After stopping illumination, no bacterial re-growth was observed (data not shown) within 24 h in the dark in the case where the residual concentration of H_2O_2 was present. For a practical application, the

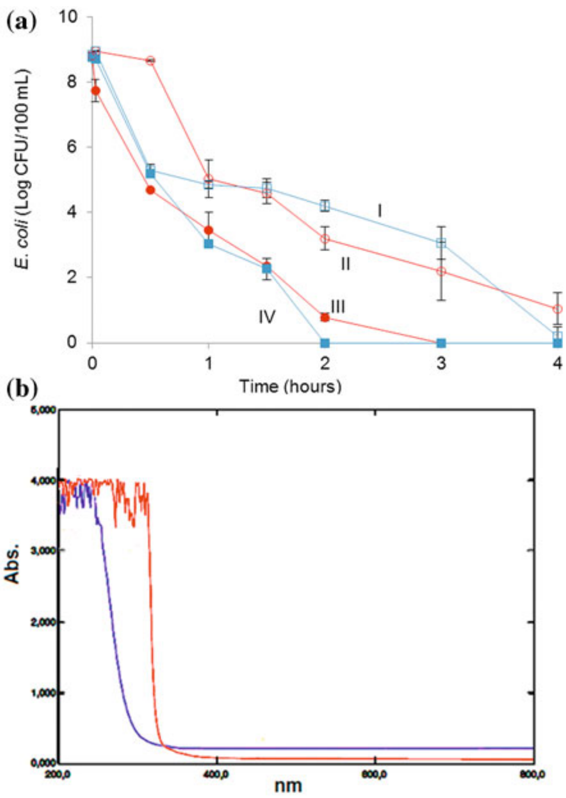

Fig. 10.4 (a) *E. coli* inactivation during: (□) simulated solar light (SODIS Control) in borosilicate bottles (I); (○) simulated solar light (SODIS Control) in PET bottles (II); (●) near-neutral photo-Fenton (Fe^{2+} 0.3 mg/L; H_2O_2 20 mg/L)/simulated solar light in PET bottles (III) (■) near-neutral photo-Fenton (Fe^{2+} 0.3 mg/L; H_2O_2 20 mg/L)/simulated solar light in borosilicate bottles (IV). Simulated solar light intensity (500 W/m). Experiments were conducted in triplicate and standard error was found to be around 5%. (b) Absorbance spectrum of borosilicate (*blue line* in the figure) and PET (*red line* in the figure)

absence of bacterial re-growth during water cooling in the dark is even more important than reaching a high *E. coli* inactivation rate during solar photocatalytic treatment.

10.4 Discussion

The maximum water temperatures achieved in the reactors under simulated solar irradiation and natural sunlight were 40 °C and 38 °C respectively. These temperatures are low compared to temperatures that are known to have a negative impact on bacterial viability (>45 °C) (Berney et al. 2006). Therefore, inactivation was predominantly due to optical, rather than thermal effects. Direct DNA damage by UV-B can also be excluded as the borosilicate and PET bottles screened UV-B between (200–300 nm) and (200–330 nm) respectively (Fig. 10.4b). Thus, part of the observed photo-inactivation could be due to excitation of exogenous (humic and fulvic acids or other dissolved NOM) and endogenous (cytochrome, flavin, tryptophan) photosensitizers, (Malato et al. 2009; Cory et al. 2009) as well as the

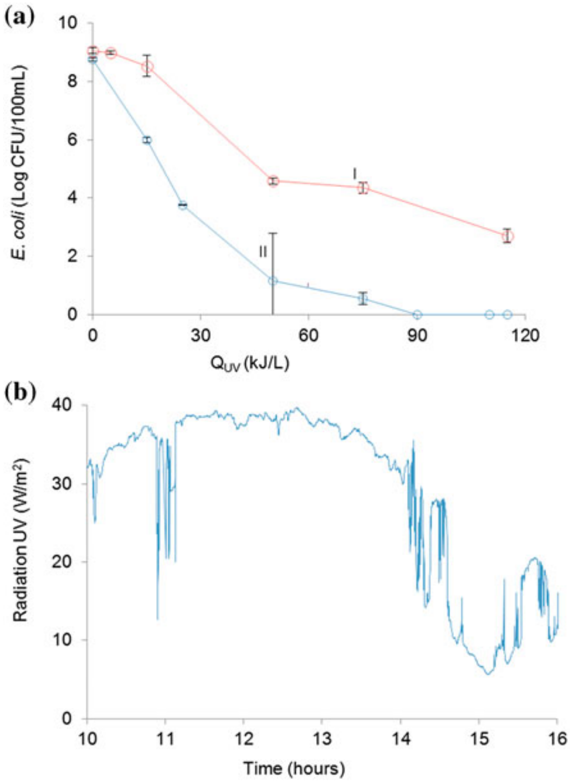

Fig. 10.5 (a) *E. coli* inactivation by sunlight in PET reactor during: solar light (SODIS Control) (I); near-neutral photo-Fenton (Fe^{2+} 0.3 mg/L; H_2O_2 20 mg/L)/solar light (II) Experiments were conducted in triplicate and standard error was found to be around 5%. (b) UV solar irradiance in Cali–Colombia during the experiment. Real time: from 10 until 16 h

ROS-action $\left({}^1O_2, O_2^{\bullet -}, {}^{\bullet}OH \text{ and } H_2O_2\right)$ generated from the dissolved oxygen (O_2) contained naturally in water (Ciesla et al. 2004; Imlay 2008). It has to be noted that natural water, contrary to the laboratory Milli-Q water, contained NOM and exogenous photosensitizers. Depending on the source and location of the ROS generated, different adverse effects are found. Exogenous short-living ROS formed outside of the cell act on the external membranes of cells. Internal or endogenous ROS can result in damage to macromolecules such as DNA and lipids. Endogenous ROS may be generated by three ways (i) by direct action of UV-vis solar radiation, which generate superoxide $O_2^{\bullet -}$ and hydrogen peroxide H_2O_2 (Halliwell and Gutteridge 1989), (ii) via internal Haber-Weiss/Fenton reactions, that may occur with internal iron (Sychev and Isak 1995), and (iii) exogenous long-living oxidative species which can diffuse into the cells, generating injuries at their interior. An example of this case is H_2O_2; which can cross membranes freely and may react with free iron present in the cells, generating ${}^{\bullet}OH$ by Fenton reactions (Imlay 2003). Photo-inactivation is simultaneously initiated by two ways: (i) photosensitization increases the intracellular presence of ROS leading to a direct attack of the membrane and other proteins; (ii) the photo-degradation of catalase, which in normal conditions would continuously eliminate exceeding intracellular

H_2O_2, allows the generation of highly reactive $^{\bullet}OH$ via intracellular Fenton reactions, leading to DNA damage. When the enzymatic defense system of microorganisms is damaged, cells die due to the accumulated damage of the different components (Imlay 2008).

The treatment $Fe^{2+/3+}$/simulated solar light enhanced solar disinfection for *E. coli*. The bactericidal effect of Fe^{2+} under light (Fig. 10.2, system (II)) probably arises from the ability of Fe^{2+} to diffuse into the cells. Fe^{2+} has a lower charge density than Fe^{3+} and therefore can move almost freely through the cytoplasm (Braun 2001). For most organisms, the uptake of Fe^{2+} is highly toxic due to it rapidly undergoing an intracellular Fenton's reaction when reacting with metabolic H_2O_2 and generating $^{\bullet}OH$. With respect to Fe^{3+} under light (Fig. 10.2 system (III)), it could be either ad- or absorbed on bacteria instead of being diffused inside the cells leading to the formation of Fe^{3+}-bacteria clusters (Braun 2001). Besides, the membrane of gram-negative bacteria does also contain highly specific binding proteins with many carboxylic end-groups likely to show an affinity for Fe^{3+} and to support the formation of photoactive Fe^{3+} bacteria bounds (Cieśla et al. 2004). This leads to the generation of ROS close to the target and is responsible for the observed inactivation in the system (III). The efficiency of the $Fe^{2+/3+}$ under simulated solar irradiation (Spuhler et al. 2010) and Fe^{3+} under natural solar light for bacterial inactivation has been described (García-Fernández et al. 2012). García-Fernández et al. (2012) observed a lethal action of the system (Fe^{3+}/solar light) during the inactivation of *E. coli* in distilled water (pH: 5.5–6) resulting in a total inactivation for 10 mg/L of iron added (1.42 mg/L of dissolved iron) after 15 min (1.2 kJ/L) of solar exposure.

The near-neutral photo-Fenton process ($Fe^{2+}/H_2O_2/h\nu$) showed higher *E. coli* inactivation efficiency compared to those found for $Fe^{2+/3+}/h\nu$ or $h\nu$ only. This high efficiency lies in the great amount of extracellular $^{\bullet}OH$ radicals in the process (Eqs. 10.1–10.3). $^{\bullet}OH$ is the most powerful oxidant generated inside the cells. It reacts instantly with no selectivity, at the diffusion limits, with sugars, amino acids, phospholipids, nucleotides and organic acids including DNA (Sattler et al. 2000). Cellular defense mechanisms against a DNA attack by $^{\bullet}OH$ do not exist. Additionally, the presence of extracellular H_2O_2 may increase the permeability of the bacterial membrane for Fe^{2+} diffusion and alters the membrane's surface available for Fe^{3+} attachment.

The comparison of borosilicate and PET bottles on *E. coli* inactivation using simulated solar light and sunlight exposure showed that even though PET bottles filtered out most of the UV-B and a significant portion of the UV-A radiation, bacterial inactivation could be compared well with the one taking place within the borosilicate bottles (Figs. 10.4a and 10.5a). These results indicate that inactivation occurs not only in the absence of UV-B, but also when there is reduction in the amount of UV-A. It could be explained by: (i) UV-A irradiation (315–400 nm) and visible light, mainly blue light (400–500 nm), also has a detrimental effect on the bacteria, chemically altering some proteins (Harris et al. 1987). Other studies claim that visible light is an important component in sunlight inactivation of microorganisms (Acra et al. 1984), (ii) by the fact that both bottles receive the required energy to reach the final disinfection result. Rincón and Pulgarín (2004) reported that bacterial suspension is inactivated once it receives a certain amount of light useful in disinfection. The efficiency of near-neutral photo-Fenton process using PET bottles to disinfect surface water from the Sahelian region, Africa was reported in our group (Ndounla et al. 2013; Sciacca et al. 2010). Both total coliforms and *Salmonella* sp. were inactivated after 3 and 4 h respectively under solar exposure containing iron (0.3 mg/L) and H_2O_2 (10 m/L) at natural pH (Sciacca et al. 2010). However, the present study is, to our knowledge, the first to present a comparative study of near-neutral photo-Fenton and SODIS in PET and borosilicate reactors. The results obtained in this paper are promising considering that PET bottles are low cost and ubiquitous in many regions of the world, in addition to other advantages such as: (i) virtually very low-cost technology compared with borosilicate bottles, (ii) their high robustness which allows them to withstand adverse environmental conditions and (iii) very low maintenance requirements. Thus, the near-neutral photo-Fenton process under solar light irradiation using PET bottles is a promising option for water disinfection in rural areas of developing countries. Finally, further studies using different natural waters having different chemical composition are required to determine the effectiveness of this system. As well, the auto-oxidation of the PET bottles during the near-neutral photo-Fenton treatment will be monitored.

However, the stability of the PET bottles to the added chemicals (Andra et al. 2011) and sunlight (Wegelin et al. 2001) is reported in literature. Wegelin et al. (2001) have shown that PET degradation products such as terephthalate monomers and dimers are primarily formed at the outer surface of the bottles and no indication for migration of possible photo products or additives into the water was observed.

When a photocatalytic treatment is applied, it is important not only to determine the time required to reach complete inactivation but also to verify that no re-growth occurs during the subsequent cooling and storing of water. For these reasons, re-growth after 24 h in the dark was measured for simulated solar light, $Fe^{2+/3+}/h\nu$ and $Fe^{2+}/H_2O_2/h\nu$ systems. As shown in Fig. 10.2 in the dark, bacterial reactivation occurs for bacteria treated with simulated solar light (system I) demonstrating that bacteria are not effectively inactivated. The recovery of the damaged bacteria and/or the cellular reproduction of the unaffected cells could occur in the dark. It is know that the cells damaged (but not killed outright) by UV radiation have two mechanisms to repair the DNA. The first, known as photo-reactivation or photo-repair, occurs after exposition of damaged cells to wavelengths of light spectrum between 300 and 500 nm (Vélez-Colmenares et al. 2012; Oguma et al. 2001). The second mode of reactivation takes place in the dark is due to excision re-synthesis and post-replication repair. In both cases, different enzymes reverse the detrimental UV photo-dimerization of pyrimidines by reforming the monomeric pyrimidine. By contrast, no re-growth was observed for the $Fe^{2+/3+}/h\nu$ treatment (Fig. 10.2, systems II and III) and a residual disinfection effect was observed continued in the dark. This occurs if Fe^{2+} diffuses into the cell and participate in intracellular Fenton's reaction. This suppresses bacterial dark repair in the presence of iron ions. In the case of photo-Fenton process ($Fe^{2+}/H_2O_2/h\nu$) (Fig. 10.2, system IV), no bacterial re-growth was observed during 24 h after stopping light exposure. These suggest a strong bacterial damage induced by the photocatalytic treatment (Fig. 10.2, systems II, III and IV).

10.5 Conclusions

Even if the inactivation rates photo-assisted by the bare presence of Fe^{2+} and Fe^{3+} in the absence of H_2O_2 are similar, the specific action mode of each ionic form is not the same. While Fe^{2+} might diffuse into the cells and cause the production of $^{\bullet}OH$ inside the cells, Fe^{3+} binds to the cellular membrane and generates localized ROS. The identification of these reactions is relevant, because iron is generally present as Fe^{3+} in natural water and represents a low-cost photocatalyst for solar water disinfection.

Field experiments under natural sunlight using a CPC reactor show potential application of near-neutral photo-Fenton process for water disinfection. The addition of 0.6 mg/L of Fe^{3+} in the presence of 10 mg/L of H_2O_2 at near-neutral pH under sunlight, leads to total *E. coli* inactivation in river water. No bacterial re-growth was observed during 24 h in the dark, suggesting that this treatment induces strong and lethal bacteria damage.

These results show the application potential of the near-neutral photo-Fenton process for bacteria inactivation using PET bottles. The addition of a low concentration of Fe^{3+} (0.3 mg/L) in the presence of H_2O_2 (20 mg/L) at near-neutral pH under simulated solar light and sunlight leads to total *E. coli* inactivation. This method has the potential to add to the number of household water treatment technologies available, thereby increasing the likelihood that a user will find a suitable option for their particular socio-economic level. The results are promising and encourage the next stages: (a) the evaluation of the effectiveness of the system in natural water, (b) the monitoring of the auto-oxidation of the PET bottles during the near-neutral photo-Fenton treatment, (c) the evaluation of economic and ecological assessment of the process, (d) the identification of the target community and finally (e) the development of a pilot treatment unit.

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Chapter 11
Appropriate Technology for Household Energy Access: The Case of the Centrafricain Stove in the Logone Valley (Chad, Cameroon)

Francesco Vitali and Mentore Vaccari

Abstract The dissemination of improved stoves can play a key role in providing poor people with an adequate energy access in contexts where biomass is the only available energy source. Burning solid fuels through inefficient and smoky stoves results in a number of negative impacts on both the users' health and budget, and the local environment. Thus, there is an urgent need for appropriate cooking technologies that use biomass in a more efficient, cleaner and easier way. This paper presents an experience in the Logone Valley (Chad, Cameroon) where models of improved stove were disseminated. The project was led by the Italian non-governmental organization ACRA—Cooperazione Rurale in Africa e America Latina (Rural Cooperation in Africa and Latin America). The activities focused on the reduction of wood consumption and the creation of income generating activities. Stove models to be promoted were chosen according to local constraints. A rigorous methodology was applied to assess the technical performance of different models that used various fuels, and were compared with traditional cooking systems. The Centrafricain stove was chosen because of the good performance in terms of fuel savings but also because of its adaptability to the local conditions. Sale rates and acceptability by the users were assessed through specific surveys addressed to the artisans trained in the stove production and to the households that adopted the improved model. The development of a self-sustainable market, subsidized by the project only in the start-up phase and the users' satisfaction prove the validity and the appropriateness of the adopted approach in the introduction of a new cooking technology.

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11.1 Introduction and Purpose

Energy is one of the basic requirements of human societies. It is vital for human life and for technological progress. Without access to efficient and affordable energy sources, people living in poor conditions have very limited opportunities for economic and social advancement. The International Energy Agency (IEA) (2011) estimates that 1.3 billion people lack access to electricity and 2.7 billion people rely on the traditional use of solid biomass for cooking. Moreover, the number of people using traditional solid biomass is increased due to population growth, the rising of liquid fuel costs and the global economic recession (IEA 2008).

The use of traditional solid fuels leads to a number of dramatic impacts not only on the users but also on the environment. In order to gather the fuel required for their daily energy needs, householders have to cover every day longer distances carrying heavy loads or have to invest a significant share of their budget to purchase it in the local market. Besides wasting a resource (for which a lot of drudgery or money was needed), the use of solid fuels on open fires or inefficient stoves results in a range of health-damaging pollutant emissions, often worsened by poor ventilation of the household (Refhuess et al. 2011). Women and young children, who usually spend many hours close to the smoky source, are the most exposed. Such emissions also have significant global warming effects, due to incomplete combustion of the fuel carbon. Moreover, the unsustainable overexploitation of natural resources leads to their fast depletion. Often (where existing) national household energy policies and strategies do not effectively target an adequate energy access, pursuing the hope to switch to more modern and clean fuels, like Liquefied Petroleum Gas (LPG), and missing to meet the financial capability and the needs of the population. This is why, especially for the weakest classes, energy poverty seems to be a no-way-out situation: there are no financial means to step up the energy condition, accessing the use of more convenient, cleaner and modern fuels and on the other side, the limited energy level provides no emancipation means, both to improve the quality of life and to eventually start a small income generating activity.

Appropriate technologies play a key role in breaking this vicious circle, allowing intermediate solutions to escape from this limiting condition. Currently, there are many technological options to use traditional fuels more efficiently. The suitability of existing improved technologies depends on such factors as availability, applicability, acceptability and affordability, as well as access to funds to cover initial investments. The decreasing availability of existing sources of fuel makes switching to modern alternatives a necessity in some places. In some others, the inconsistence of a market not supported by realistic energy strategies makes access to more appropriate fuels unaffordable for most of the people, which is going back to traditional cheaper fuels. According to these aspects, and to the expected increasing number of people relying on biomass for cooking purposes in the next future, the adoption of improved technologies, which allow to use poor fuels, but in a convenient, cleaner and more efficient way, appears to be a viable way to reach the goal of minimum energy access for the poor.

11.2 Design and Methods

The approach adopted in this study is strongly influenced by the considerations reported above. A specific context, the Logone Valley at the border between Chad and Cameroon, was the one where field observations and activities were implemented. The research was conducted through the activities of an international development cooperation project (ENV/2006/114-747) implemented by the Italian non-governmental organization ACRA and funded by the European Union. At the beginning of the project (2008), charcoal and wood were the traditional fuels for household energy supply in the region. Only in urban areas some high income families used to cook with LPG gas. Charcoal production and sale have been forbidden by the Chadian national government since 2009. This has had a shocking effect on local wood prices that more than doubled, from 15 francs CFA/kg (0.02 €) in 2008 to 40 francs CFA/kg in 2011 (0.06 €). The project aimed at the reduction of wood consumption at household level. The dissemination of low-technology but high-efficiency models was implemented according to the socio–economic conditions of the local people—minimal investment capacity due to the very low level of income—and of the skills and the tools available for small local workshops—in particular the lack of electricity resulting in basic manufacturing capabilities.

11.2.1 Stove Models Tested

Two different models were tested, the Centrafricain stove and the Ceramic stove (Fig. 11.1) in order to identify an improved cook stove (ICS), locally reproducible and affordable by the majority of the population. In order to give an in-depth comparison on the household energy technological options available on site, also a gas-stove and a three stone fireplace were tested. The three stone fire is the traditional, most common and affordable cooking system in use, while LPG is the clean modern fuel supposed to replace solid fuels, according to the national household energy supply strategies (AEDE 2002; HELIO International 2009).

The Centrafricain ICS is formed by a metallic structure assembled without welding with a clay ring surrounding the combustion chamber. A good compromise between a design with smaller-mass components (to reduce thermal inertia) and durability, affordability and user acceptance, as suggested by Jetter and Kariher (2009), was obtained with this stove model. The combination of metal and clay allows longer operational life span in comparison with other simple ceramic models. The clay ring increases the stability, resistance and efficiency of the stove.

Fig. 11.1 Different wood stove models tested in the study (3-stone fire, ceramic stove and centrafricain stove)

Moreover, the Centrafricain stove was designed to accommodate the local round-bottom pots, making it possible to cook according to local traditional practices. The addition of two handles ensures the portability of the stove. A local research center (Centre des Technologies Appropriées de Maroua—CTA) studied the model optimizing the design and adapting the manufacturing process to local practices. A technical manual for the reproduction of such a model has recently been written by the authors in collaboration with researchers of CTA in order to standardize the dimensions and the manufacturing process. Within the project activities, trainings aimed at creating the skills for the production of this model were addressed to local artisans. According to observations on site, final unit prices of the Centrafricain ICS vary between 5,000 and 7,500 CFA francs (7.62–11.43 €).

11.2.2 Testing Protocol

Stove performance greatly varies according to different operational conditions. Testing allows implementers to learn how well stoves perform and to quantify improvements in fuel efficiency (PCIA 2010). Stove Performance Tests were conducted according to procedures recommended in both the VITA International Testing Standards (VITA 1987) and the revised University of California at Berkeley (2004) standard testing protocol series. The full range of testing protocols available was implemented in different missions in the field in order to assess different aspects of the stoves. In particular, in the first missions on site (in 2009 and in 2010) different fuel-stove combinations were tested using the Water Boiling Test (WBT) protocol, in order to give a full overview of the cooking options available in the local market.

In the second mission (2010) a number of controlled cooking tests (CCTs) were performed on some selected ICS models, chosen for the dissemination, in comparison with the traditional local cooking system, the three stone fire. This protocol allowed to assess the wood consumption of the tested stoves in the preparation of a typical local food.

In a third mission in 2011, a Kitchen Performance Test (KPT) was performed in order to prove the actual fuel savings realized by the users in their day-to-day cooking. This entirely field-based procedure is carried out over several days in the users' households and evaluates the effect of stove interventions in real-world conditions.

Table 11.1 sums up the methods used to assess the impact of the dissemination of the Centrafricain ICS in the Logone Valley. Each method allowed to assess a relative indicator considered meaningful for the assessment of the impact on a certain aspect. Indications on the quality of indoor air were obtained through 24 h monitoring of two main pollutants, carbon monoxide (CO) and particulate matter.

11.3 Results

11.3.1 Technical and Real-Use Performance of the Stove

A number of tests were conducted on site to evaluate which stove model, in combination with proper fuel, could be suitable for the dissemination among the local population of the Valley of the Logone River. Test results presented in this

Table 11.1 List of indicators used to assess the impact of the centrafricain ICS introduction

Impact	Subject	Indicator	Method	Reference
Technical	Stove	Performance outputs	WBT	Bailis et al. (2007)
	Artisan	Skill evaluation	Checklist	
	Market	Availability of materials and items	Observational survey	WHO (2008)
Social	Household	Adaptability to local cooking practices, acceptability	Semi-structured interviews	Barnes and O'Sullivan (2007)
Economic	Household	Wood daily consumption	KPT	Bailis et al. (2007)
	Household	% of fuel expenditure on household budget	KPT, semi-structured interviews	Bailis et al. (2007), WHO (2008)
Health	Household	IAP[a] reduction	IAP monitoring	Bruce et al. (2007)
Environmental	Household	Wood consumption reduction	KPT, CCT	Bailis et al. (2007)
	Project	CO_2 savings	AMS II.G	UNFCCC (2011)

[a] IAP = Indoor Air Pollution

section are summarized for synthesis purposes, but are fully available in Vitali (2012). Water Boiling Tests performed on site showed the better effectiveness of proposed ICS models in comparison to the traditional ones from energy and economic points of view (Collivignarelli et al. 2010). Actually, worse performance was achieved in comparison to benchmark energy use for woodstoves (MacCarthy et al. 2010). That is due to the low level of technology and standardization in the manufacturing process of the tested stove models. Nevertheless a lower performance can be acceptable in exchange with a number of advantages in terms of sustainable and simple reproducibility and adaptability to local practices.

The performed CCT showed even more the effectiveness of the proposed improved stove models in terms of fuel savings. In particular the Centrafricain stove allows a significant reduction of wood consumption (−35 %) in the preparation of a typical local meal in comparison to traditional cooking systems (Vaccari et al. 2012).

The daily wood fuel consumption was the main output of the KPT performed in different households both for three stone fire and Centrafricain ICS. Averages resulted 1.15–0.51 kg/d per capita for the three stone fire and the ICS respectively. Thus, a 55 % reduction in wood use can be stated by the adoption of the Centrafricain stove.

Data regarding the IAP were collected in three households involved in the KPT. A total number of six 24 h monitoring periods (three for the three stone fire and three for the Centrafricain ICS) were performed. Data were compared to WHO standards for IAP (WHO 2010). The guideline value of 25 $\mu g/m^3$ 24 h mean was taken as reference for $PM_{2.5}$, while for CO all the value levels averaged on different time periods were considered. Some differences in the cooking practices and in the number of prepared meals were evidenced even in the same household during the monitoring periods. Therefore, in order to avoid any bias due to a change in the behavior of user, cooking events were analyzed specifically. Table 11.2 shows the ranges of arithmetic means calculated for the whole monitoring period (24 h) and for the specific cooking time. Cooking time observed in the monitoring periods were similar to the one observed during the CCTs (i.e., 2–3 h). The level of both the monitored parameters decreased with the use of the improved stove. Actually values observed were coherent with those indicated in literature for IAP from household fuels (Naeher et al. 2007), but did not meet the WHO indications for air quality, in particular for particulate matter. On average, a 30 % reduction of CO indoor concentration and a 36 % reduction of $PM_{2.5}$ occurred on the whole monitoring period, while no significant differences were noted on the specific meal preparation time.

11.3.2 Technical Skill and Production Evaluation

Artisans' skills were assessed after the trainings in order to evaluate the understanding and the ownership of the manufacturing procedure. The technical

Table 11.2 IAP ($PM_{2.5}$ and CO) level measured in household monitored

		WHO air quality guideline value	Three stone fire	Centrafricain ICS
$PM_{2.5}$ ($\mu g/m^3$)	Arithmetic mean	25	287–1,416	133–1,193
	Meal	–	452–7,344	271–2,624
CO (ppm)	24-h mean	6.1 (7 mg/m^3)	3–29	7–20
	Meal	–	20–97	14–90

evaluation was done using a list to check the single specific operations described in the manual. Many difficulties for trained artisans occurred in the final assembly of the stove, in particular in adhering to correct details and measures. That was probably due to the poor technical equipment and tools available for their activity. Given this constraint and the impossibility to provide them with modern tools (for instance electricity is not widely available in all the local workshops), a step-by-step illustrative manual was produced in order to assure the respect of the standardized procedure and measures by means of an easy guide. Simple tools and screens for the reproduction of the shapes were provided as an incentive for the participation to the training workshop. According to visits that followed in the later months, technical skills of the artisan that produced the highest number of stoves were significantly improved, even if a rigorous ex-post assessment was not done due to the impossibility to re-contact all the trained artisans.

The production trend was assessed during the different phases of the project using structured interviews to the trained artisans to record the number of stoves sold. Only the first tranche of the stoves was partially subsidized by the project (in Fig. 11.2 the first 420 units at a discounted price of 3,000 CFA francs (4.57 €) instead of 6,000 (9.14 €)). The number of stove sold illustrated in Fig. 11.2 refers to the cumulative number given by each interviewed artisan, considering as the starting point the date of the training workshop organized by the project. The number of Centrafricain stoves sold in the following periods by nine out of the 17 artisans trained area was 2,944, with an average sale rate equal to 113 units per month. Number of sold stoves is not a direct indicator of the continuative adoption of the stove by the users. Nevertheless, some indicators prove the success of the introduction of such a technology in the common local practices:

- *growing sale rates*: the sale rates more than doubled, passing from 47 units/months in 2009 to 113 in 2011, without the help of any subside, according to estimations based on data collected during visits to artisans;
- *positive stock ratio*: according to internal reports, the stock ratio was about 25 % of the total production, showing a lively manufacturing activity;
- *spontaneous diffusion of the ICS model*: out of the trained artisans, some moved their business and organized new workshops, also in other regions of the country.

The graph in Fig. 11.2 also shows the trend in sale of the Ceramic ICS. This activity was strongly subsidized by the project, as 50 stoves were commissioned to

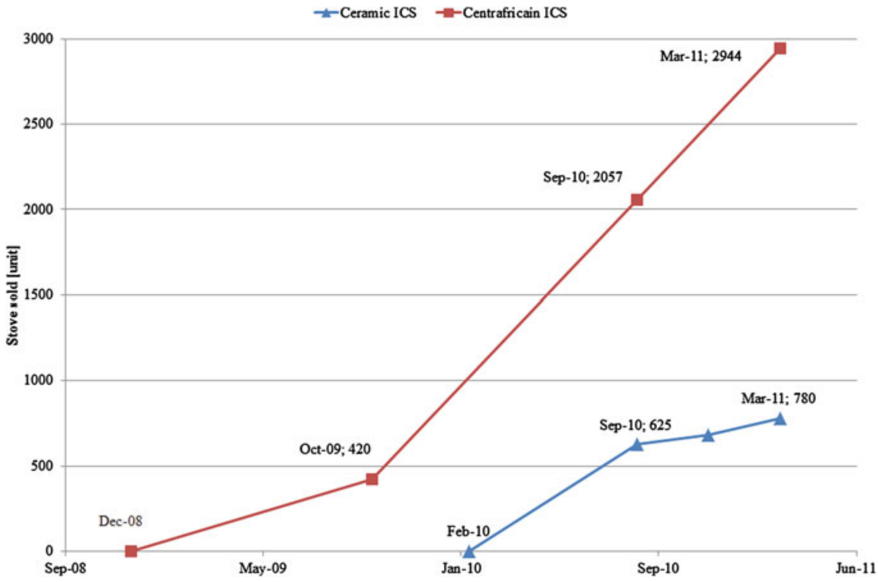

Fig. 11.2 ICS sale rates during different phase of project

12 out of the 19 women trained to ease the start-up of the activity. According to sale rates observed in following visits, the diffusion of such a model results slower than for the Centrafricain ICS: in particular a significant contribution is given by the incentive of the project, whose share is greatly higher than the share sold autonomously by the women trained. This may be due to the over-simplicity of the Ceramic ICS. This stove model is not very likely to be proposed for commercialization on a large scale, but it is rather more appropriate for a self-manufacturing, especially in rural areas where women own the traditional skills in ceramic production.

11.3.3 Adoption and Acceptability

Adoption and acceptability of the Centrafricain ICS was assessed through a total of 77 semi-structured interviews to some of the early-adopters of the proposed improved stove. This survey allowed understanding some local cooking patterns before and after the adoption of the improved stove and some social characteristics of the householders interviewed. The totality of the interviewed people was women in charge of the daily preparation of the meals. The median size of the family was seven people. The median age of the interviewed was 30 years: this indicates that the adoption of improved cooking system is more likely to happen where the person responsible for the cooking is young and more open to innovative improved system. Regarding the cooking practices before the adoption of the ICS,

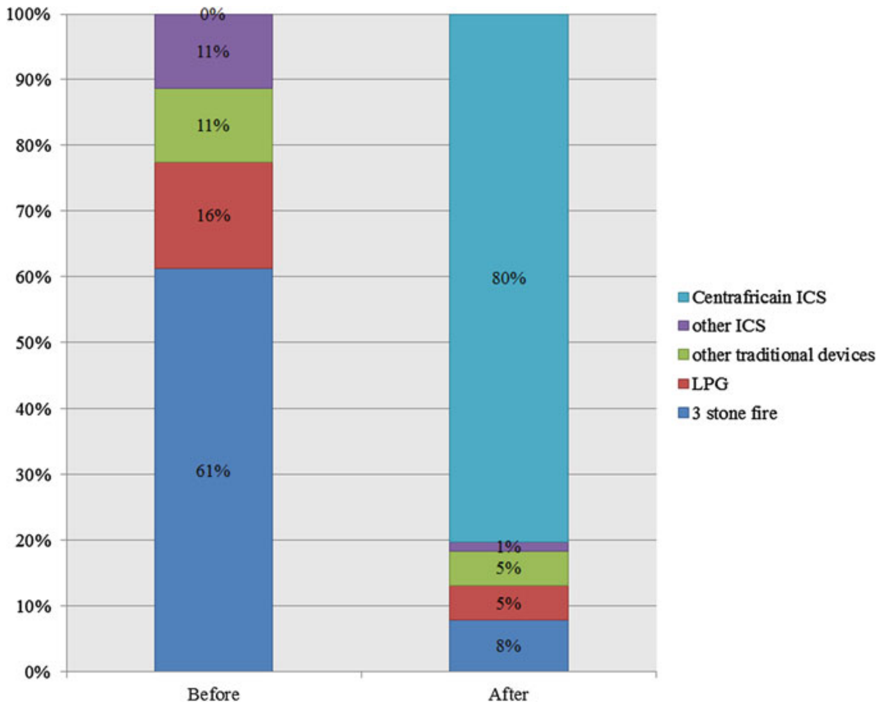

Fig. 11.3 Cooking system used before and after adoption of centrafricain ICS

the 64 % of the interviewees used the traditional three stone fire, 30 % other traditional systems and 18 % LPG.[1] Figure. 11.3 shows the change of cooking device by the interviewed. A large share (80 %) of the interviewed used the Centrafricain ICS as the only cooking device, while the remaining 20 % used it in association with other systems. The share of households still using the three stone fire, which was the majority before the intervention, reduced drastically, even if 8 % of the interviewed declared still to use that rudimentary system for certain preparations. The share[2] of household that dropped the use of LPG after the adoption of the Centrafricain ICS indicates the higher convenience of such a more simple technology. This last output is particularly interesting because shows that some users that early switched to more modern fuels like gas went back to the use of wood pushed by convenience, ease of use, continuity with traditional practices and affordability.

[1] Total sum is more than 100 % because 9 % of the interviewed used more than one cooking device.

[2] Thirteen percent as the difference between LPG users before (18 %) and after (5 %) the adoption of the Centrafricain ICS.

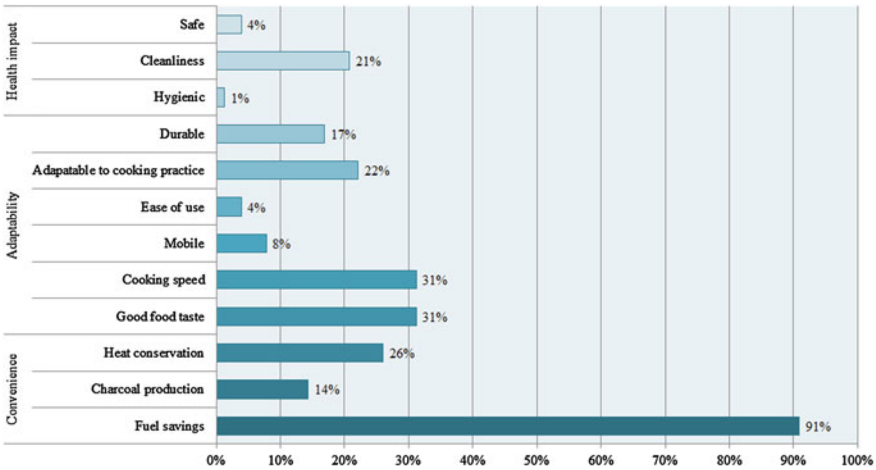

Fig. 11.4 Advantages stated by householders that adopted the centrafricain ICS

An open question was finally posed about the advantages perceived in the use of the Centrafricain ICS. No specific aspects were suggested by the interviewer in order to reduce possible influences in the answer. People interviewed pointed out more than one advantage, as reported in Fig. 11.4. The vast majority indicated the reduced wood consumption and the consequent fuel and money saving as the main advantage. A number of different aspects linked to the adaptability of the stove to local cooking practices were indicated, such as good taste of food, cooking speed, durability and transportability.

11.4 Conclusions

A number of tests were conducted on site to evaluate which stove model, in combination with the proper fuel, could be suitable for the dissemination among the local population. Stove models were chosen among traditional and improved stoves already available in the region and tested according to international recognized standard protocols (WBT and CCT). The two models, chosen for the dissemination (through the training of local artisans), were the Ceramic and the Centrafricain ICS. Both of these were selected not only for their good performance, but mainly for the appropriateness to the local context in terms of acceptability by the users and suitability to the local technical skills.

Result-based impact assessment was done by means of a number of surveys both quantitative (KPT, IAP monitoring, CO_2 avoided emissions) and qualitative (interviews, observations). Increasing adoption rates (more than 3,500 units sold at March 2011) and appreciation by the users indicate the appropriateness of the stove model proposed by the project to the local context. Reduction in fuel consumption (−55 % for the Centrafricain ICS in comparison with the traditional three stone fire) and adaptability to the local cooking practices are the main features indicated by the users as drivers of the technology. These aspects have been fundamental for the successful scaling-up of the Centrafricain stove's dissemination.

Material availability on the local market and the ownership of the manufacturing technique of the trained artisans indicates that the intervention proposed was feasible under a technical point of view. The Centrafricain ICS model can be easily reproduced by local artisans using already available tools and skills. Some issues about a more controlled quality of the production have been pointed out. Actually due to the simplicity of the stove, a not very rigorous standardization of the ICS is required. Some stove characteristics and measures may be improved in order to achieve even better results in terms of technical performance, even if a cost-benefits analysis of a further improvement of the technology should be done according to outputs of the local context.

Observations on site prove the creation of a self-sustainable market and a continuative adoption by householders, in particular in urban areas where fuel is purchased. In rural areas, a lower adoption rate was observed. That is likely to be due to the cost-free wood collection, impacting the household activity only in terms of time and not of budget. Therefore, in those areas, fuel saving is not seen as a priority, and the user does not perceive the economic benefit of ICS use.

An appropriate scaling-up strategy should be planned in strict contact with the local authorities, in order to better address the proposed cooking systems to the household needs, both in rural and urban areas.

According to the increasing sale rates, the overall positive impact of the introduction of the Centrafricain ICS, in terms of savings of wood and money and avoiding emissions, could be even higher. The reduction of the environmental impact, such as the reduction of the IAP level, are not very relevant to the sensitiveness and the priorities of the users, therefore they are not likely to be promotion factors in the dissemination. Nevertheless, the experimental results obtained prove the appropriateness of the Centrafricain ICS also under this point of view.

Acknowledgments Francesco Vitali conducted this research within the PhD course in "Appropriate Methodologies and Techniques for International Development Co-operation" of the University of Brescia, supported by the Alberto Archetti Fund.

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Part III
How to Ensure an Integrated Sustainable Development?

Chapter 12
Towards Sustainable Integrated Development? Partnerships and Systems

Martin Dahinden

Abstract Over the past centuries, western civilization has been marked by increasing specialization and division of labor. It has furthered its understanding of the world around it by deconstructing it into ever smaller pieces. It has created a vast array of disciplines and sub-disciplines to predict, or at least to explain, behavior in nature, individuals and society. Today, however, western civilization is faced with an increasing number of complex phenomena of which it does not know precisely how they will unfold or interact. This makes it imperative to re-direct development efforts towards increased sustainability including all its aspects: economical, social and environmental ones.

12.1 Introduction

Spectacular advances in information, communication and transportation technology have boosted the trade and exchange of goods, services and information all over the world. Many countries and societies have benefited. At the same time, regulatory challenges and risk management have become more complex, as witnessed during the ongoing financial crisis in Europe and elsewhere. The ongoing degradation of the environment, the growing world population and the increasing resource scarcity make it imperative to reorient development efforts towards increased sustainability. This, in turn, increases complexity.

To efficiently address today's complex challenges, a multidisciplinary approach is necessary. More interdisciplinary research and analysis is needed to tackle increased complexity. The task is to integrate data, methodologies, perspectives and concepts from multiple disciplines in order to advance fundamental

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understanding of interlinked real world problems. Interdisciplinary research requires individual researchers to gain a deep understanding of more than one discipline. Multidisciplinary teams assemble and create a common language and framework for progress and innovation.

The Swiss Agency for Development and Cooperation (SDC) is trying to create new and innovative forms of cooperation to deal with global risks in the context of development and poverty eradication. The fact is that neither pure policy-level interventions nor activities confined to the project-level alone can bring about the desired change. With the new Global Programs in the areas of climate change, food security, water, migration and—soon to be added—health, SDC wants to address important global risks and challenges at the policy and the operational levels, backed by targeted research and analysis.

To reduce global environmental risks and at the same time increase local development benefits is no easy task. Individual households, but also market-oriented companies will only accept a new technology if it is proven and financially viable. Just being environment- or climate-friendly is not enough. The best is of course if a technology comprises all of these qualities, but often there are difficult trade-offs.

When the poor are forced to choose between low-paid work in a polluting brick factory that is dangerous to their health, or no work and no income at all, they will choose the former. If cutting trees around the house is the only way to survive in the short term, even if it endangers the livelihood in the longer term, the trees will be cut, for lack of alternatives.

Interventions "for the common good" should also benefit those directly concerned and provide them with real options and alternatives. Such solutions, however, are often not readily available but must be identified and developed first.

12.2 Tackling Global Challenges and Reducing Poverty: A Double Dividend

An intervention that reduces greenhouse gas emissions and at the same time provides workers of a factory with safer working conditions (thanks to new low-carbon technology) is producing a "double dividend". In addition, such interventions also tend to translate into additional benefits, such as increased productivity.

India's economy is growing fast and so are its greenhouse gas emissions. By promoting the use of energy-efficient technologies in small and medium enterprises, SDC not only helps to reduce CO_2 emissions but also to decrease production costs and to make working places safer, for example in brick production. By supporting 650 small and medium enterprises, SDC has been able to contribute to the reduction of some hundreds of thousands of tons of CO_2.

Another example of a win–win situation is the development of new plant varieties that are resistant to changing precipitation patterns in the Peruvian Andes.

Peru is particularly exposed to the effects of climate change. By integrating these new crops into a broader agricultural development framework, involving local and Swiss academia, local, regional and national governments, and non-governmental organizations, SDC promotes adaptation to climate change and helps to improve the food security of some of the poorest communities in the country.

Still another example is securing access to clean water while at the same time protecting watersheds and the ecosystems thanks to state-of-the-art wastewater treatment technologies. SDC supported such projects in a number of villages in Moldova where 90 % of the rural population uses water from wells that does not meet modern quality standards.

Once innovative solutions have been introduced and successfully tested in one part of the world, the goal is to replicate them in other regions. Here, policy-dialogue on the regional or global level is a main facilitator. SDC's Global Programs take an active part in this dialogue.

In order to elaborate and implement such projects and programs, SDC relies on the knowledge, expertise, and experience of its partners in civil society, the private sector, and academia. Research is a powerful tool, and technological, social and political innovation is a "must" to achieve a more sustainable economic, social and environmental development in rich and poor countries. That is why SDC will invest 72 million Swiss Francs over the next 10 years in solution-oriented (applied) research on global issues. Effective communication and application of research results is a priority, and must be an integral part of the research activity.

12.3 Technology Transfers as a Door Opener

Successful technology transfer requires flexibility and adaptation to local circumstances. If SDC works on clean air initiatives in China and new private or state actors turn up during the implementation process, SDC must find ways to include them. The evidence shows that careful adaptation to local decision mechanisms should be prioritized over strictly sticking to a project document defined at the beginning of the implementation process. Adaptive management is needed.

Successful technology transfer leads to mutual trust and credibility. This, in turn, opens doors for scaling up or for additional areas of intervention in (often sensitive) socio-economic issues such as living and working conditions, gender, poverty or child labor, where such intervention would otherwise be unthinkable. In other words, technology transfer can serve as a pragmatic entry point to promote broader and further-reaching development goals.

New technology often has an impact on diverse groups in a country. Therefore, cooperation with the most relevant stakeholders is needed if balanced and equitable development is to be achieved. SDC projects assume the role of a systems manager which may involve a policy dialogue with the partner government, coordination with other aid agencies, or cooperation with the private sector in the partner country.

Evidence from SDC's work also shows that multi-partnership arrangements have proven less risky than working with single partners. In a multi-partnership arrangement, the withdrawal of one partner can be more easily absorbed.

Technology development and deployment is a powerful tool to tackle not only global challenges such as climate change or food insecurity, but to improve at the same time living conditions of the local population, to reduce poverty and to open doors for more sustainable development pathways. Like any other development cooperation activity, technology transfers require time. Only by considering the social, political and economic realities on the ground, success is possible. For this, close cooperation between development actors, science, the private sector and civil society is needed.

SDC as a development agency relies heavily on innovative ideas that have the potential to gradually change the lives of poor people for the better.

Chapter 13
Innovation in Multi-Actor Partnerships: A Waste Management Initiative in Vietnam

David Christensen

Abstract *Access2innovation* is an initiative based in Denmark that develops and tests innovative new ways to build and implement strategic partnerships between civil society, business and academia. The objective is to meet perceived market opportunities and challenges in developing countries by developing innovative sustainable technological solutions and business models through partnerships. In this paper, an action research study is presented involving the early stage development of a commercial venture addressing waste problems in Vietnam involving CARE International and Danish companies in the waste management sector and carbon market. As facilitator and mediator, the author has sought to align objectives and bring about a business idea involving waste handling technologies. In the study, it is shown that going from an initial needs assessment towards a business idea is challenging, although some keys to success lie in providing actors with a sound base for decision-making as well as active bi- and multilateral negotiations. As a novel experiment, the study shows that *access2innovation* can provide a platform conducive for partnership-based innovation for development.

13.1 Introduction

This paper presents some preliminary findings from an initiative that distinguishes itself through its innovative approach to supporting sustainable, commercial ventures in difficult developing and emerging markets. The initiative, termed *access2innovation*, develops and tests new ways to build and implement strategic partnerships between development NGO's, businesses and academia.

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The objective of the initiative is to meet market opportunities and challenges in developing countries by developing innovative sustainable technological solutions and business models through such partnerships. Specific thematic areas for *access2innovation* are renewable energy, water and sanitation and food security. The initiative is driven forward by an interdisciplinary, network–administrating secretariat which the author has been part of since 2011 as an action researcher and member specializing in management engineering, with a further specialization area in technology assessment.

Access2innovation is an initiative based in Denmark running for a total project period 2011–2014, and is what may be seen as an experiment in building and implementing partnerships between disparate sets of actors. Working to turn needs and challenges into market opportunities, its secretariat counts specialists within project management, management engineering, business modeling and development studies and has in the past drawn on competencies within user-driven innovation and anthropology.

External parties involved as partners in the *access2innovation* initiative include several Danish universities, business interest organization as well as Danish branches of international NGO's—among them CARE, ActionAid, the Red Cross, and the World Wildlife Fund. The full list of participating project partners is shown in Table 13.1.

The rationale for bringing disparate partners together lies in the initiative's premise that synergies may be found in combining the competencies found in multi-actor partnerships involving all parties. The specific propositions are listed below (Ravn 2012), while the overarching model followed by *access2innovation* is illustrated in Fig. 13.1.

- For NGO's, the proposition is that these types of organizations gain access to better tools for operational activities in their relief and development work. NGO's provide their partners with local expertise and networks in developing countries.
- For businesses, the proposition is that they gain access to new knowledge, networks, improved positioning and new markets. Companies enter into partnerships with vital technical know-how as well as production and marketing capabilities.

Table 13.1 *Access2innovation* participant organizations

Development NGO's	Business interest organizations	Universities
CARE Denmark	Confederation of Danish Industry	Aalborg University
MS Actionaid Denmark	Northern Jutland Food Network	Copenhagen Business School
Danish Red Cross	Danish Water Forum	Copenhagen University
World Wildlife Fund	Renewable Energy Innovation Network, Danish Technological Institute	

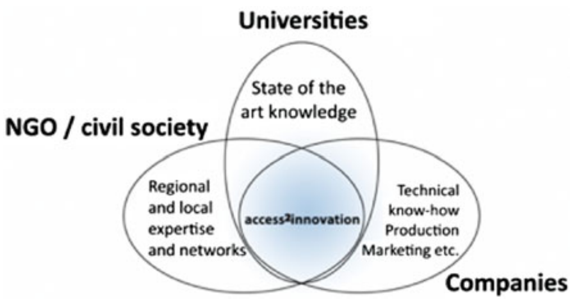

Fig. 13.1 *Access2innovation* illustrated

- For universities, the proposition is that these knowledge institutions get an expanded base on which to pursue their core activities within research, higher education and societal engagement. They gain access to new knowledge and research areas, and enter into partnerships with state-of-the-art knowledge.

These propositions have been tried out in a previous incarnation of the *access2innovation* initiative in 2007–2011 running on a smaller scale than the current set-up. This pilot initiative achieved remarkable results in generating entrepreneurial spin-off companies addressing needs and challenges in humanitarian mine–clearing activities, which was the departure point for the pilot (Ravn 2012). Among others, the pilot initiative launched SkyWatch, a company producing a remotely controlled multi-rotor aerial vehicle for digital mapping of a mine–clearing area. It also produced ViewWorld, a company that developed a mobile phone application specifically designed to assist aid workers in field reporting. Though these examples will not be dealt with in detail, they serve to illustrate that *access2innovation* can serve as an institutional infrastructure that in the innovation management literature is seen as crucial for addressing networked innovation processes (Van de Ven 1986).

As part of the *access2innovation* initiative in its current incarnation and as member of the secretariat, this author has facilitated a multi-actor partnership centered on developing a business idea for handling of waste in Vietnam. The background for becoming engaged with waste management in Vietnam to begin with was because of the prompting of a development NGO (CARE International, in Denmark and Vietnam) that identified a specific need for private sector involvement and presented it to the *access2innovation* secretariat. CARE Vietnam sought private sector assistance after identifying the problem of a lack of formalized waste handling in the coastal communes of the country where the NGO operates, south of Hanoi. In these communes, CARE Vietnam observed that waste was indiscriminately disposed of directly to the surrounding environment. This negatively affects their activities, because domestic household waste (specifically plastic bags) stunt the growth of mangrove saplings that have been planted as part of a CARE Vietnam coastal disaster risk reduction and climate adaptation project.

The case study presented in this paper is based on action research, with the author assuming the role of facilitator and mediator in a multi-actor partnership.

Table 13.2 Partnership participants

Partnership participant	Description
CARE Denmark	NGO; Danish subsidiary of CARE International
CARE Vietnam	NGO; Vietnamese subsidiary of CARE International
Company A	Contracting business; Organic waste and residual waste management, especially composting
Company B	Engineering consultancy; Management of energy projects including carbon projects in transition countries, with an express wish to expand into developing countries
Company C	Municipally owned limited company; Not-for-profit, municipal public waste management service delivery
Company D	Engineering consultancy; Specializes in bioenergy systems, quality management and training
Company E	Engineering consultancy; Specializes in environmental and geotechnical construction with an already established presence in Vietnam
Company F	Engineering consultancy; Specializes in waste management consultancy services

The case study exemplifies how the *access2innovation* principles work in practice, and centers on the early stage development of developing a commercial idea based on CARE Vietnam's needs assessment and wish to collaborate with businesses. Specifically, it includes the involvement of a number of Danish companies operating in the waste management sector and carbon market. The full list of actors involved in the process is given in Table 13.2.

13.2 Design and Methods

13.2.1 Action Research

Because the author in the case study is inextricably part of the phenomenon, the scientific approach may be best aligned with *action research*. Action research brings together action and reflection. It links theory and practice and puts emphasis on participatory, democratic processes in practical knowledge production and the creation of solutions to issues of pressing concern to people and communities (Reason and Bradbury 2010).

The role of the researcher under this set of scientific principles is dualistic. Goduscheit et al. (2008) frame this quite simply, based on a Danish inter-organizational network study similar to *access2innovation*: when conducting action research, the researcher works as both an *observer* and *problem-solver*. In this sense, action research aims at taking action as well as generating knowledge or theories about that action, giving rise to a delicate balancing act between the roles. In the context provided by *access2innovation*, this author therefore facilitates and constructs as much as observes and evaluates. Coughlan and Coghlan (2002) point to the same kind of dualism, stating that action research projects typically consist of two distinct elements: the actual change project involving some kind of action, and the research project based on that change. These elements in the case study designed are seen as follows:

- The change project is the process of getting the Danish companies in the waste management sector and carbon market to collaborate with CARE Denmark and CARE Vietnam in the formation of a business idea.
- The research project seeks to understand how business and development concerns are negotiated against each other in the social setting provided by the partnership. Due to the novel constellation of participants, one could reasonably expect that there will be issues of contention between these concerns.

13.2.2 Data Collection Methods

The empirical data-collecting methods used by the author have been those of an interactive field practitioner and process facilitator. This consisted of workshops, bilateral and trilateral meetings, phone conversations, email exchanges, field observations and field notes.

In addition, documents have been key for the partnership process in the sense that they have formed the reference point for discussion, dissent, negotiations etc. between the participants in the partnership. These have included:

- Internal CARE Denmark documents;
- Workshop summaries;
- A Terms of Reference for a consultant field study in Vietnam;
- A consultant report conducted on the basis of the Terms of Reference;
- A Danish company memo on the carbon credit potential of the project;
- An application document to a governmental, Danish private sector support mechanism for developing countries.

While the data-collection methods may have lack the robustness of more ‘traditional’ methods, e.g., questionnaires among the partnership’s participants, or conducting formal semi-structured interviews, some arguments go some way towards addressing this. Firstly, there is the richness of data, which comes from multiple sources: from personal interaction at different levels of communication with the people and organizations involved, as well as textual artifact documents. Secondly, there is the timeframe. Because the partnership has been running for the duration of a year, any observations have had a chance to play out throughout this period. Any issues raised during the case study have had a chance to become robustly embedded in discussions throughout the duration of the process. The study is not a simple snapshot picture of a partnership collaboration process taken at an arbitrary point in time, but a study of the process in its entirety so far.

13.2.3 Constructive Technology Assessment

A special note should be made concerning the use of participatory action research methods in the above process; this author has employed the use of *Constructive Technology Assessment* as a guiding methodological framework. Technology assessment is a discipline usually thought of and embedded within policy studies and sometimes mistakenly equated with solely an engineering approach. In general terms, technology assessment is a set of methodologies that are utilized to help assess the potential positive or negative impacts that may follow in the wake of introducing a new technology of any conceivable type (Coates and Jarratt 1992). Though not focused exclusively on technology development *per se,* the activities in *access2innovation* imply that careful foresight is necessary concerning the technological elements on which any business model is developed. This is especially due to the low-income and/or marginalized groups that are likely to be affected by a commercial intervention in a developing country.

Historically, technology assessment has mostly been applied in setting whereby experts and scientists undertook retrospective assessments of known technologies and providing incontestable answers (Remmen 1991; Schot and Rip 1996). More recently, a shift has been made from being *diagnostic* and *reactive* in such occasions to becoming *predicting* and *constructive* in conditions requiring more agility, and in more fluid situations when the context of a technological development and its impacts is highly uncertain. Such conditions are argued to be embodied in the partnerships settings provided by *access2innovation*. To address the increasing uncertainty of many technological developments, constructive technology assessment relies on the practitioner-researcher to be interactive and promote more democratic, participatory decision-making. A characterization of constructive technology assessment, contrasted with traditional technology assessment, is illustrated in Table 13.3. The important point to be made is that the practitioner–researcher no longer is tasked with finding the right answers to a

Table 13.3 Traditional technology assessment versus constructive modes of TA (Remmen 1991)

Traditional Technology Assessment	Constructive Technology Assessment
Dominance and authority given to science and scientist-practitioners	Users and scientist-practitioners engage in dialog
Provides the direct consequences and effects associated with a technology	Specifies both goal and methods as well as consequences and problems
Limited problem analysis	Emphasizes a problem analysis
Focus on technical solutions	Combines a number of possible solutions
Results provided in a report	The results are provided through design
Tool for decision-making	criteria, a report as well as dissemination
Linked automatically (technocratically) with parliamentary decision-making processes	Provides a 'catalytic effect'
	Interlinks with different arenas of decision-making
Finding the right answers	***Asking the right questions***

given problem complex, but is instead tasked with making sure that the right questions are asked.

Most recently, the technology assessment literature suggests that concerning developing countries, constructive types of applied technology assessments have their greatest applicability (Ely et al. 2011). This is seen to be because they are flexible enough to make use of networks of actors to fill in institutional capacity gaps often seen in resource-constrained governments. In this light, it can be argued that *access2innovation* appears to follow the general call for including diverse stakeholder groupings to participate in technology assessment processes in developing countries.

13.3 Results

A narrative of the case study explaining the process is given in the following.

Step 1—Initial Needs Assessment: First, CARE Denmark made an approach to *access2innovation* requesting assistance for a business partnership idea centering on waste management in Vietnam. At this point CARE Denmark was already established as a participating partner in *access2innovation*. Upon receiving the request for assistance, *access2innovation* responded by asking CARE Denmark to reformulate their problem identification into a Terms of Reference for a further in-depth study of the problem area. The background for CARE Denmark's request for assistance was explained as follows:

- CARE Vietnam had for four years been involved in a community–based climate change adaptation and disaster risk reduction project involving mangrove tree planting in coastal areas of Thanh Hoa province, south of the nation's capital Hanoi. This was a coastal disaster risk reduction and climate change mitigation project. The project had major problems with untreated domestic household waste, in particular plastic bags washed in from inland and further up the coast that become entangled with the tree saplings and stunting their growth. Attempts to secure funding for a root-cause waste management project have failed.
- CARE Denmark has become interested in establishing relations with Danish companies and adopted a formal policy to this end in 2010. Additionally, Danish companies are perceived by CARE to be at the 'cutting edge' in terms of waste management know-how and technology.
- Perceived positive developmental effects in addressing the waste situation in Vietnam are apparent. Untreated amounts of waste are only increasing due to the country's largely unchecked economic growth, and the negative environmental and health problems are unfairly distributed towards poverty-affected groups. There is also a potential for job creation if a waste management intervention is made.
- Traditionally a purely private sector-oriented support program, the so-called Danida Business Partnerships program under the development cooperation arm

of the Danish Ministry of Foreign Affairs is a funding source that had recently opened up to enabling NGO participation in the commercial ventures it co-finances. This, coupled with the fact that CARE Denmark's traditional funding sources at the Ministry of Foreign Affairs were being phased out, increased CARE Denmark's interest in the Danida Business Partnerships (DBP) program and in collaborating with Danish companies in general. Additionally, the guidelines from the Danish Embassy in Vietnam were quite clear in stating that they strongly favor commercial business ventures under the DBP program featuring the use of 'green' technology.

- CARE Denmark was an active member of the *access2innovation* project and seeks to make use of their support in early stage commercial venture development be-tween NGO's and Danish companies.

As for the Terms of Reference submitted by CARE Denmark, these established:

- Waste management problems were real, pervasive and affected CARE Vietnam's mangrove project in the coastal communes in Thanh Hoa province.
- There were at present unclear roles and responsibilities on behalf of the Vietnamese authorities throughout different levels of government to address rural waste issues.
- There was a lack of any formal, proper disposal facilities for solid waste present in the target communes, located in two specific districts of Hau Loc and Hoang Hoa in particular.
- There had been aborted previous attempts at commune level for household waste collection schemes because of a lack of proper disposal facilities, and aborted attempts at district level to attract bidding for establishing such facilities.

As its objectives, the Terms of Reference established the following goals:

- To analyze the waste management situation and waste-to-energy potentials in five target communes and at least one town in Hau Loc and Hoang Hoa districts in Thanh Hoa province.
- To make recommendations for a project to address the waste management situation in the area.

Step 2—First Interactive Workshop: The Terms of Reference formed the basis of a first interactive workshop, in which a number of companies were identified and invited to discuss the draft contents of the study in accordance with what they saw as important from their own business perspective. During this workshop, the companies also voiced how they saw themselves as being involved in the partnership. The companies were identified through private networks at both the *access2innovation* secretariat and CARE Denmark.

The main output of the workshop was a consensus that there was no reason to delay the in-depth study. Upon explaining the conditions for *access2innovation* to support paying for the in-depth study by man-hours in kind supplied by the companies and CARE Denmark, the workshop participants agreed that this could be done by holding a follow-up workshop after the consultancy assignment was conducted. The second workshop would have the function of having the companies come together to discuss the findings and decide upon the next steps in the partnership.

In effect, this was a workshop output that alleviated many of the uncertainties involved in the initiative: by adopting a stance that insisted upon data from the consultancy assignment first before committing fully to becoming a commercial partner in the initiative, the collective sentiment was 'wait-and-see'. In this manner, the Vietnam initiative held the companies' attention until further light could be shed on the waste management situation in the target communes.

The Terms of Reference was accepted by the *access2innovation* secretariat to be supported financially. As a research initiative supported with external funding, *access2innovation* has the discretionary mandate to disperse of such support funding on condition of in-kind contributions from the organization or organizations applying for such funding.

A support package of 50,000 Danish Krone (approximately 6,700 €) was released from the secretariat to support a consultant to carry out the in-depth study of the problem area. As agreed with the participating companies and CARE Denmark, this amount was to be released on the condition that the same corresponding amount was to be provided in-kind by the partners in terms of man-hours.

Step 3—Providing a Decision Base: Once the Terms of Reference were accepted, an external consultant was identified to carry out the field study in collaboration with local consultants. The external consultant submitted a draft, then a final report on his findings.

The main conclusions in the study by and large confirmed the overall picture assumed to begin with, but provided greater detail of the waste situation. The study was able to provide more specific information about the volumes and composition of the waste, where it came from and also showed that the informal recycling sector was active to a certain degree in the surveyed areas. In the most populated commune in the surveyed areas, a rudimentary solid waste collection system existed with a number of waste collectors using pushcarts and a small fee for service. However, the system only served to collect urban waste for direct disposal to coastal waters. In no place among the surveyed areas was there any final handing of organic waste other than direct dumping to the surrounding environment.

Step 4—Second Interactive Workshop: After the external consultant submitted the findings, the *access2innovation* secretariat organized another workshop to discuss the report. This second workshop was crucial because it provided the venue and forum for the participating companies to coalesce a more tangible business idea together. While the innovation process as a whole may have begun the moment *access2innovation* reacted to CARE Denmark's request for assistance in Vietnam, there was no real business development process to speak of until the consultancy report was handed in. The report provided a decision-base from which the participating companies would be in an improved position to assess their continued commitment, leading to the formation of an actual business idea.

During the workshop, the partners discussed their differing interests in the waste management initiative. Two companies dropped out of the entire process prior to this workshop after having seen the consultancy report. Company E was too occupied with existing commercial activities to consider continuing with the Vietnam initiative, while Company F was a smaller consultancy company that did not see a business case in the submitted material.

For those companies that did come around the table to participate in the second workshop, they did eventually move to coalesce around a specific business idea centered on the utilization of composting and biogas technology on a minor scale and specifically including poor and vulnerable groups in the business model as paid waste collectors. The revenue streams in the business idea focused on sales from biogas and digestate/fertilizer production as well as carbon credit sales. In this manner, the idea made use of the different core competencies that existed in the partnership. There was some back and forth discussion among the companies concerning how the initiative was to consider commercial scalability to begin with, or whether the initiative should first start out with a small-scale pilot phase. Both considerations had implications for the technologies to be implemented, as well as how it would address development objectives in line with CARE Vietnam's priorities. A large-scale and centralized waste handling plant would have implied a greater catchment area than what CARE Vietnam was initially prepared for, and would have had fewer opportunities for involving poor and vulnerable groups as waste collectors in the business model. Electricity production and carbon crediting would however be at a commercial scale more in line with the mainstream for such technologies. In contrast, it was reasoned that a biogas facility dimensioned to fit with the small local solid waste production amounts might not be commercially feasible to begin with and might imply problems relating to continuous biomass supply, but would have a greater potential for social inclusion and development impact.

Two lead company contenders emerged from the workshop: companies A and B. The *access2innovation* secretariat had to subsequently hold bilateral meetings with each of the companies and with CARE Denmark in order to come to an agreement about which one was to ultimately take the lead role. Company A ended with taking the role, mostly on merit of being a contracting business and technology provider rather than being a consultancy. As such, it was reasoned that it would be easier and more in line with Company A's core business to direct investments towards building up the waste handling facilities locally.

Step 4—Business Development: Based on the input from the second workshop and through the bi- and trilateral meeting between the *access2innovation* secretariat, the companies and CARE Denmark, the basis began to be laid for a concrete business idea to be submitted to the Danida Business Partnerships program, a Danish governmental support scheme for private sector development in developing countries. The business idea outlined in the support scheme application ended up being granted support funding from the Danish government. Initially, the government support facilitated only a field visit to Vietnam by representatives of the participating Danish companies in the partnership. The field visit, as well as subsequent visits to Vietnam by Danish company representatives, identified a number of potential local partner companies in the business idea. Currently, an in-depth feasibility study (a further and more detailed decision base) is being worked out as the business idea continues to undergo further maturation with the support of the *access2innovation* secretariat.

13.4 Conclusions

In the attempt to facilitate multi-actor partnerships, the Vietnam case study shows that the *access2innovation* approach has shown some real effects in ensuring the stability of disparate actor constellations, spanning the NGO and business sectors, in the process of developing a business idea. Through interactive workshop methods in the spirit of a constructive technology assessment ('asking the right questions'), this author has facilitated reaching a common set of objectives for a waste management business idea in Vietnam with positive development effects. Seen in this light, the *access2innovation* case study shows that an interdisciplinary network-administrating secretariat can provide the institutional infrastructure to manage the complex task of going from an initial NGO-driven needs assessment towards garnering commercial interest and crystallizing a business idea, making use of a multi-actor partnership. As a novel experiment in its initial stages, the case study shows that *access2innovation* can provide a platform that is conducive to network-based technological innovation for development.

There is a caveat, however. The task given to *access2innovation* is not easy, and many factors remain beyond its control. Even the presence of a dedicated network administrating secretariat does not guarantee 'buy-in' to a business idea from companies in a difficult market environment, and even financial support to spur momentum in a partnership process does not guarantee results by the same token. For example, this was carried out in the case study when the *access2innovation* secretariat released funds for a consultant to provide an in-depth analysis of the waste management problem in Vietnam. The initiative saw the opt-out of two companies that were initially involved in the partnership. Yet despite this, the partnership lives on, and it is with this note that this author highlights the innovative value of the *access2innovation* approach, as the partnership enters into a more decisive phase of maturing and testing out the business idea.

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Chapter 14
Instrumental Participation in Serbia: Online Platform for the Dialogue about Public Spaces, Their Availability and Public Usage

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Abstract This paper elaborates on the collaborative online platform for spatial resources in Serbia. This is an existing solution for the bottom-up involvement of stakeholders and communities in the revivification of non-functioning public spaces, a hideous legacy of the communist era compounded by the transition period and today's neoliberal practices. This platform was launched on a web site in 2009 as a community-driven initiative to challenge uniform and centralized decision-making processes regarding the availability of special resources in order to gradually and systematically change Serbian society's attitude towards institutionalized democracy, participatory processes, and urban sustainability. Any built environment always reflects political and economic processes, especially in turbulent social circumstances, such as the disintegration of Yugoslavia's socialist system (destabilization of the institutions and the social value system). This situation continued to thrive in the wake of the break between socialist and neoliberal urban policies. A series of derailed political rights and deviant market initiatives culminated in the maximization of land use, suburbanization, and the general decline of the community and its culture. Such a scenario was possible due to the disintegration of existing zoning regulations and the lack of up-to-date ones, the collapse of key urban institutions, and the inability to react to rapid change during the transitional period, which finally caused the vast majority of visible urban, spatial and social conflicts. This paper will present how this participatory, online, user-friendly activity motivates inhabitants to engage in the public life of their city

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and, being exposed to the proof of urban problems, understand the need to participate in the decision-making process of the city's genesis. Such a tool demystifies and specifically designates social actions in the transition period. This quality makes the platform applicable to a wide range of social contexts, regardless of their particular spatial characteristics.

14.1 Introduction: Serbian Transitional Arena

Like other transitional economies in Central and Eastern Europe, Serbia experienced dramatic social, economic and political changes at the end of the twentieth century. The abrupt shift from a communist regime, based on a centralized economy, to that of a neoliberal, market state economy, resulted in turmoil, which, aggravated by regional nationalistic conflicts, left powerful imprints on all aspects of Serbia's social organization and spatial development.

Urban space is essentially molded by a wide range of complicated, entangled social processes, and regulated by social institutions. The quality of social activities depends on the physical structures within which they are placed. Bearing this in mind, urban development in Serbia during the transitional period has been continuously hindered by political instability, convergent socio-economic forces and inconsistent planning systems (Vujošević and Nedović-Budić 2006). Urban planning procedures and strategies were rendered inefficient in addressing urban conflicts at all spatial levels. This was due to the privatization of land and urban structures, the decentralization of government, and an abundance of urban stakeholders with blurred rights and responsibilities chiefly governed by not-yet-regulated market forces.

This chaos at all levels of society, compounded by a lack of background in theoretical research and a scarcity of practical experience within this new context of market economy and decentralized political and administrative powers, underlined the need for substantial change in the manner of dealing with the growing number of local urban issues. The ineffectiveness of the centralized, top-down approach of the communist era, in addition to the failure in successfully replicating more advanced models of western neoliberal economies, made it clear that a fragmented, small-scale approach to spatial and social conflict could achieve more long-term, consistent, and far-reaching results.

The focus of the informal, problem-solving strategy thus shifts to public space, which is both an essential prerequisite of social cohesion and a common denominator of urban issues in a broader context. Thriving public space allows social capital to be formed, participative democracy to be grounded and economic development to be determined. Public space, in terms of urban structures and open spaces, is a solid base and an active framework of social interactions in the city (Harvey 2008). How space is organized defines the intensity, quality and durability of interactions among urban actors. Moreover, stimulating urban actors to take an active part in solving the urban problems of their immediate surroundings supports the idea of “the right to the city” (Harvey 2008), which encompasses the right of every citizen to the resources of the city and to freely participate in the life of their local community (Lefebvre 1991).

14.2 Public Space—A Venue for Exercising Rights to the City

According to its core definition, space poses the vital basis of mankind’s relationship to the outside world, while the built environment shapes its sense of identity. Therefore, the primary quality of an urban environment is a specific place with its identity—public space.

The urban transformation of Serbian cities falls into the cliché of the new post-socialist urban reality that emerged during the “transition to markets and democracy” (Tsenkova and Nedović-Budić 2006). During previous socialist times, the notion of public space was suppressed in everyday discourse with less opportunity to fight the negative influences, thus opening up the possibility for private capital to enter the privatization process and to dispose of property, which necessarily reduced society’s democratic potential and eventually led to totalitarianism. Public spaces in Serbia suffocated under the weight of the neoliberal dictates of profit as people strove to implement western models, fulfill market economy targets and redefine national identity. The tendency of profit-driven private users to occupy public space in market economies converts cities into antisocial areas, which only have value if they become a source of profit. Historically, public spaces have played an important role in promoting democracy and public participation in social affairs. Diverse social identities, individual urban actors and groups mingle in public spaces, which become indicators of the level of freedom and tolerance that prevails.

Even in socialist Yugoslavia, public space was defined as the venue for actions and interactions among individuals, but was completely controlled by one actor only: the state–the only protagonist of decision-making, spatial strategies, and actions. Through its centralized system of institutions, the state governed spatial development policies and the division of jurisdictions among urban actors according to their political status. Civil rights were restricted to the predefined common public good prescribed by the state and its political ideology.

At the end of the 1980s, when the dismantlement of the socialist regime in Yugoslavia and Serbia started, and in the 1990s when it became widespread, the function of public space (primarily the street) was radically altered to become a venue for the struggle for human rights—freedom of speech, movement and actions. Expecting to gain more freedom, people fought to replace socialism by a new neoliberal order. Unfortunately, this transition, which is still in progress, has brought subtly controlled and carefully restricted freedom.

Although the idiom "consumer society" may sound worn out, it can help identify the essential problems imposed on spatial and social order in Serbian cities, due to the transition. Public space becomes instrumentalized and reduced to a source of profit. As public and private interests collide, the most powerful economic actors usurp public space. The balance between economic, political and social powers in an urban environment is thus disrupted. This neoliberalist economic trend threatens the rights of average urban actors to use public space, so that they themselves start to organize individual actions and struggle to fulfill these rights. To achieve a functioning, participative democracy, society should ensure cultural diversity, as well as active communication and collaboration between different social and urban actors and groups in public spaces.

Within such a confusing social and political system, citizens are neither well informed about their rights, nor conscious of their responsibilities towards the public and social good. The privatization and ideologization of public spaces are non-transparent procedures, blurred by the influence of powerful investors and political bodies. In short, citizens are not aware that they need to be involved in the development of their cities. Their activities in public spaces could be practical examples of the citizens' individual expression of freedom and responsibilities in order to surpass the negative influences of transition by building their immediate surroundings and active participation in the development of their city, influencing its overall constitution and appearance. Encouraging the average urban actor to take an active part in social affairs can be but positive, for it reduces their passive roles as mere consumers of a growing, global mass culture, and endows their urban existence with an active purpose: the design of their urban environment and the control of their urban experiences.

14.3 The Instrument of Participation: The Dialogue about Public Space

In socio-geographical terms, Serbia is today endowed with significant spatial potential arising from its central position in the Balkan Peninsula. This is, however, mitigated by the uncertain transitional period resulting from the dismantlement of socialism and the constitution of national states in the last few decades. In such insurmountable consequences, this state and its inhabitants not only crave a new approach to current social and urban problems, but also a new interpretation of the modern concept of society and communication. In this respect, the availability of spatial resources becomes the lynchpin for the systematic move of Serbian society towards institutionalized democracy, participatory processes and urban sustainability.

After the Law on Free Access to Information of Public Importance was enforced in 2004, and the Law on Public Ownership was proposed in 2009, the Civic Initiatives Youth Programme launched an official appeal to all municipalities and cities in Serbia, asking what assets they had and how they could be accessed by young people. The idea was to create a virtual register of all public spaces in public ownership in order to map their distribution, identify the interest of urban actors or civic groups in using them, and define legal procedures to obtain them.

This collaborative approach through an online platform is particularly important as a community-driven initiative to allow informal groups to obtain access to space resources obstructed by unclear procedures, conditions, institutional responsibilities, and lack of information. Citizens can therefore increase their awareness of public spaces in general. Local initiatives to access space can be strengthened, and information can be spread to all interested parties, enabling them to form a common front that can pressurize institutions to address the largest number of focal points.

Therefore, this campaign aims to ensure:

- Direct cooperation with NGOs and local communities to raise awareness of the issue of space utilization;
- Dialogue and cooperation with institutions concerning the collection of data, legal procedures and practices;
- Public discussions on each and every case in order to have a clear and updated presentation of every urban and spatial conflict.

Access to the official records of municipal assets was the first hurdle to be overcome. Another setback was the problem of ownership. The campaign was stuck in a legal void. It turned out that the government authorities owned all property, and that municipalities and cities were the sole administrators of said property. On the other hand, before the adoption of the Law on Public Ownership (September 2011), a great many assets and public spaces were “lost” to the public and became privatized.

The Civic Initiatives Youth Programme first had to focus on areas where different groups and organizations (especially youth) had already started an initiative to obtain space. By continuous association, dissemination of information, workshops, official and unofficial meetings, and introducing regional experiences, they tried to inaugurate another campaign pillar to bolster all formal and informal groups, organizations and individuals, who started space acquisition initiatives.

In May 2010, the Civic Initiatives Youth Programme sent a request to Serbia’s 160 municipalities for a copy of the records of all public spaces in their possession, for an explanation of the procedures to obtain said spaces for temporary, occasional or permanent use, and for the name of the body responsible for implementing these procedures. The second round included specific requests for the legal acts in the real estate records, as well as the possible transfer of the real estate or the authority to manage the real estate, from the state to the municipal level (see Fig. 14.1).

Positive results of good practices started to emerge, by means of consulting, directing, assisting in strategizing, negotiating with local authorities, and conducting actions for the revival of public spaces. Once a group identifies the public space that they want to “conquer”, they start negotiating with the local authorities–or they appropriate the space immediately (by arranging it, gathering in it,

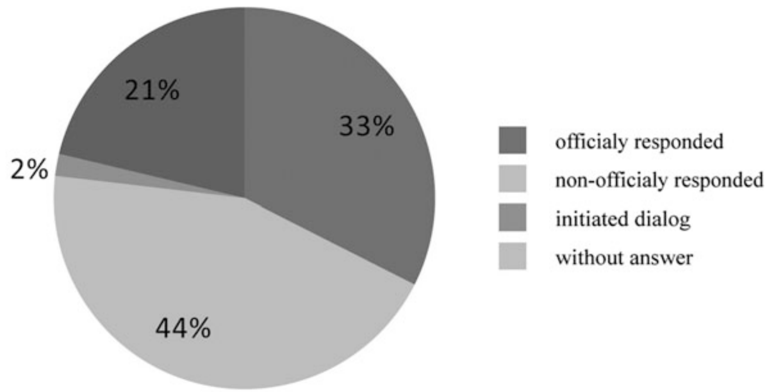

Fig. 14.1 How authorities in Serbia treated the request for legal acts in the real estate records

or conducting various artistic interventions/activities in the space). It is most important not to give up even though there may be a negative outcome of negotiations, or disapproval. Unlocking public space takes time. It requires continuous action, ideas and persistence.

Thus far, the dialogue to obtain public spaces had gradually modified the system through small strides and initiatives. Institutions and local authorities are often biased in negotiating and can be narrow-minded, uninformed, slow and centralized in decision-making. As an umbrella to all of these initiatives and groups, the Civic Initiatives Youth Programme aims to provide support, advice, and contacts through "Openly about Public Spaces"; they will regroup and unite the actions undertaken to accomplish an important element of a democratic society: citizen participation in community life.

14.4 Modern Technology for Development: Online Platform

The initiatives described above revealed that the local authorities (municipalities) do not have an official register of the public properties in their ownership. "Openly about Public Spaces" supports the idea of giving abandoned or non-used public spaces to citizens, artists, youth organizations and NGOs. To classify the information gained and better manage the development of the project, it was agreed that the abundance of information on different public spaces should be sorted into a register. This would include mapping the spatial distribution of "public spaces", and collecting relevant data about the public spaces; i.e. the legal framework to obtain them, their physical state, and social interest in their revival.

Current trends of virtualizing social life via the World Wide Web and Web 2.0 bring into perspective the production of an online platform to enable average urban actors to discuss these issues. The ease of access to information through Internet, as well as the possibility of instant communication regarding eventual focal points, has modernized and simplified the participation of citizens in matters of spatial resources in Serbian cities.

While preparing the online platform, it was important to achieve maximum impact and to develop an effective map with a minimum of expended funds. The technical platform itself is set up with free software (*Ushahidi*) and free editable Google Maps. *Ushahidi* is the open source platform designed for different types of mapping and data collection.[1] Due to the needs of the local community, the software is translated into the Serbian language and implemented with a very easy and clear graphical interface.

The platform is very simple to allow an average user to better understand its content. It consists of informative and communicative components (Otvoreno o javnim prostorima 2010). The informative section contains a virtual map of Serbia, in which all identified public spaces are located and categorized, and a database giving textual, graphical and legal information about each space. Communication within the platform is enabled through a message-contact option, news feed and blog (see Fig. 14.2).

New public spaces are classified and added to the map as soon as information about them is validated. To date, the platform has identified public spaces in more than 30 cities and towns in Serbia. According to physical and functional characteristics, these public spaces are divided into three categories (see Fig. 14.3):

1. Unfinished urban structures,
2. Abandoned buildings and places, and
3. Public spaces that have been partly used, with non-used facilities.

These categories were defined to clarify and streamline the actions to obtain the public spaces that fall into each separate category, which are themselves subcategorized in the same manner, depending on their physical state: good, bad or very bad condition (Otvoreno o javnim prostorima 2010). The latter helps potential users of the space to plan their actions and the specific usage of the selected space.

In addition to mapping, the communication part of the platform is concentrated around a dialogue box in which site visitors can type in locations and receive information should anyone else enter data on the map related to that particular location (comments and discussions) (see Fig. 14.2). The overall idea is to carefully examine, tackle and eventually solve each case.

Being that accessibility of information and availability of special public resources constitute factors of social development towards a participatory democracy and systematic civic activism, the idea of coordinating practical actions, organization and information tools through an online platform, represents a significant shift in methods and techniques to deal with urban conflicts and spatial development. The recognition of the importance of modern means of

[1] More information can be found athttp://ushahidi.com/

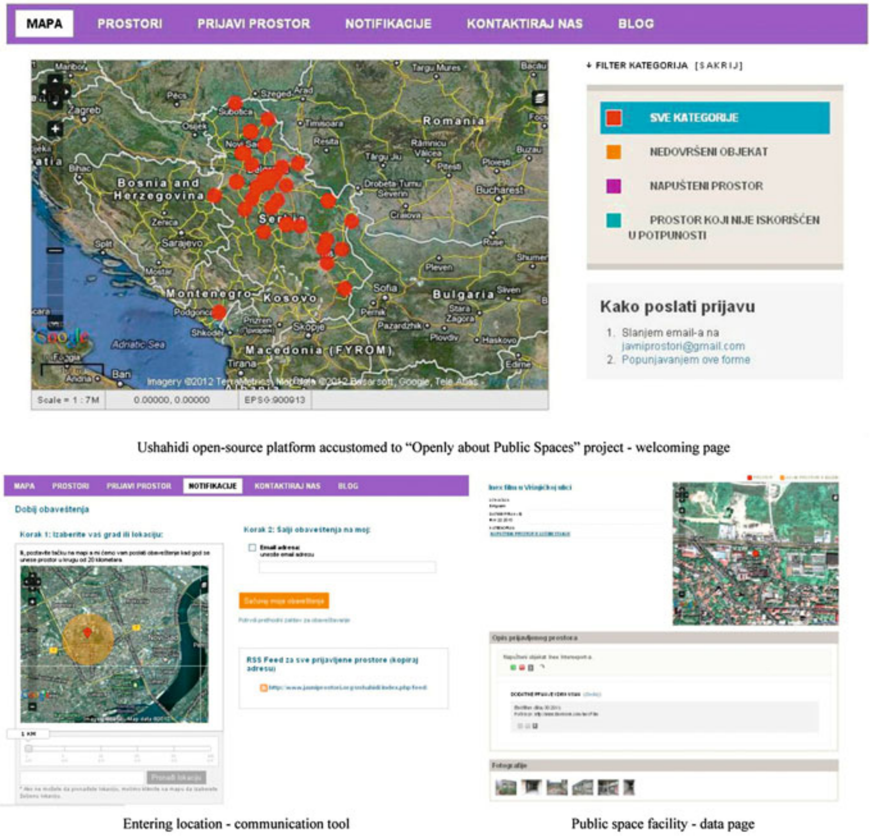

Fig. 14.2 Online environment of the platform "Openly about Public Spaces"

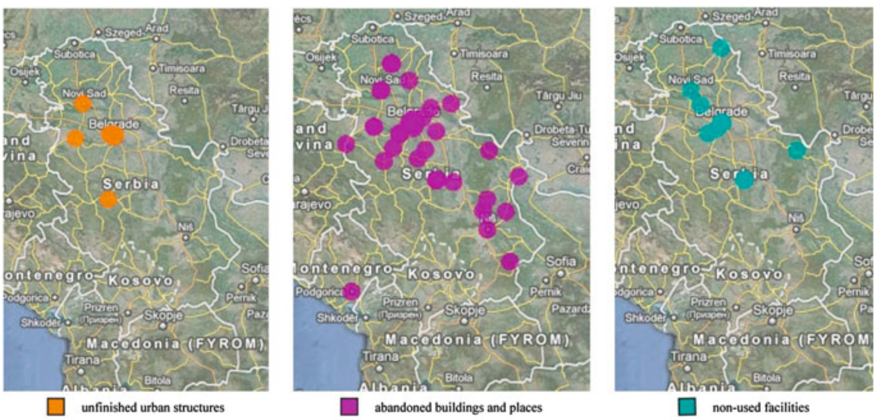

Fig. 14.3 Spatial distribution of the identified public spaces on the interactive map of Serbia

communication and distribution of data, and their appropriate use in coordination with social activities, has gained ground—but on a small scale. Nevertheless, the legacy of the ill-decoded processes, which underpinned the transition from a deteriorating form of socialism to the inappropriate dissemination of capitalism and a neoliberal economy, is still deeply rooted.

14.5 Beneficiaries: Case Studies

The platform's online activity resulted in practical commitment through the Civic Initiatives Youth Programme's "Openly about Public Spaces" campaign. Armed with collected, classified data, and willing to collaborate with institutions and diverse stakeholders, this program gained significant success in its first two years of existence.

For example, the owner of a building in Belgrade, which was once the central office of Inex Film, gave young people permission to use rooms in the building, as he had no intention to invest in reconstruction anytime soon. As a result, more than 10 associations, youth groups and independent artists are currently working on arranging and renovating this large abandoned 1500 m^2 building (Veselinović and Stevanović 2012). Thus, the building has now been given a purpose and is used by the same actors who fought for its revival.

One of the first cases was the 100 m^2 public space in the "Studentski Grad" local community in New Belgrade. This was successfully allocated to the associations "Context", "ApsArt", and the "Carina" informal scene, which belong to the "Cultural Network of New Belgrade" Association (NBKM), for their artistic activities from September 2011 until February 2012. What is more, they are released from having to pay all costs related to the space. The associations themselves decided to provide the Municipality of New Belgrade and NBKM with quality artistic programs and advanced cultural activities (Veselinović and Stevanović 2012). The broader social purpose is to create the institutional framework within which the associations that obtained this public space are also given the opportunity to jointly create new cultural value at the local and municipal levels by an independent cultural scene.

The other project was the "Bezistan" Street Gallery, launched by the "MicroArt" organization, which highlighted the problem of abandoned space and its untapped potential. It was an abandoned and devastated street passage in the city center of Belgrade–and "MicroArt" proposed its reconstruction as a venue for cultural and artistic productions. "Bezistan" Street Gallery is a unique project in the way it refers to the physical disposition of the elements in space as well as in its program of gallery activities, which consists of engaged art that addresses vital social issues. The cooperation of city authorities, municipality, and citizens' associations established a new model of dealing with neglected public spaces in order to set up the innovative and unique principle of the displacement of the Arts in public spaces for cultural purposes (Veselinović and Stevanović 2012).

Through coordinated action with the Civil Initiatives Youth Progamme, all of these actions were launched by individuals, informal groups and associations, using the “Openly about Public Spaces” campaign and online platform. These actions were in response to the lack of public spaces for individuals and groups involved in community, educational, cultural, artistic, recreational and social activities, and to the lack of venues for interaction among these individuals and groups. The overall aim is a joint commitment to fight for new urban space as creative public zones, from which all citizens could benefit.

14.6 Positive Results in a Broader Social Context

The idea of an online platform for participation in “The Dialogue about Public Spaces” arose from a deficient post-socialist context that lacked the institutions to support creativity and innovation. While the transitional environment has shown potential for significant changes in most of the civil sectors, it is actually only in recent years that independent Cultural and Youth Offices and NGOs have begun to emerge; but their influence is still weak and provisional. Therefore, the idea of collaboration on public space issues strengthens the social impact of these organizations and individuals, thus extending the influence of all urban actors, and calls for the legal responsibility of all institutions and stakeholders involved in the process.

Having identified a multitude of public spaces without clear purpose or function, the idea was to make the entire society benefit from opening up non-used public spaces to all urban actors, groups or organizations. The positive notion is that every allocated public space is a bonus for all. “Keeping” abandoned, not finished or partly used buildings, factories, parks, etc., in order to gain economic profit in some distant future, is of no use to anyone. Giving these unused spaces real purpose and endowing them with a social function, even if temporarily and for a very short time, is an obvious advantage not only for the actual users, but also for society as a whole.

Bringing the question of public spaces to open debate reinforces the determination to strive for a better definition of theory and terminology, as well as the understanding of their practical use. Based on the updated activities within the scope of the “Openly about Public Spaces” campaign, public space is identified as a field that serves all citizens in meeting their needs, and should be clearly defined in all aspects of state policy. Its main purpose is to put forward the cultural and social development of Serbian cities in times of transition, in order to enrich their urban and social life with cultural and artistic activities; namely, to move culture out of classical institutions (theaters, galleries, museums and cultural centers) into public spaces and closer to the ordinary experience of urban life.

The objectives reached by this campaign may be identified as follows:

- Demystifying public space issues;
- Relocating issues about public space from the spheres of business, politics and potential corruption, to the spheres of public interest and the common good;
- Enabling public accessibility to information and data about public space, real estate ownership, state property and their status, and the possibility of leasing;
- Increasing the availability of public space for citizens and associations, with an emphasis on youth organizations, groups and initiatives;
- Increasing transparency regarding the work of institutions and public authorities in relation to public spaces; and
- Increasing awareness by citizens of their opportunities, rights and responsibilities with regard to public space in general.

14.7 Conclusion

Started as a small-scale collective action for social activities and virtual networking and collaboration, the "Openly about Public Spaces" campaign and online platform for dialogue about public spaces aimed primarily to increase the citizens' awareness of public spaces, and to provide them with the tools and information to officially claim their right to use these spatial resources. Its initial role was to gradually impact the distribution of power, and to influence the use of public space during a confusing transitional period, that had been worsened by 40-years of socialism and totalitarianism. This coordinated action, therefore, not only increased the consciousness and democratic potential of Serbian society, but also brought it closer to modern trends by its use of low-budget, popular technological tools (such as the Internet).

One of the main spatial development issues of any transitional environment is the challenge of strengthening local initiatives in the battle for public space, as a means of applying pressure on institutions to solve a large number of problems. What is even more important is to reinforce said development by similar future actions so as to extend the cooperation of all parties involved, forming a common front to fight the negative elements of cities and countries in transition.

Finally, this virtual participation tool represents a new interpretation of cities, their design, social and spatial development. The importance and demonstrative power of culture and the arts have been revealed in the hitherto undertaken actions of the "Openly about Public Spaces" project on spatial resources, their revival and design. Art in public spaces has always had the power of transmitting the message of the community, promoting social and cultural values, and emplacing the idea of collective consciousness. In other words, this project proves that a set of prepared, and organized cultural and artistic activities, supplied with the very resources for their implementation, is also a tool for political promotion and communication between the authorities and the public, in order to establish a new and improved social order.

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Chapter 15
Towards Sustainable Urban Livelihoods and Poverty Reduction in Gaza: The Role of Partnership and Appropriate Technology

Al Moataz Hassan and Maysara El-Essy

Abstract Gaza experienced an Israeli-Palestinian armed conflict in 2008–2009. The conflict resulted in mass physical destruction and deterioration in the quality of life. The local authorities prepared plans for reconstruction to restore the living environment for the affected population. Several projects were proposed including the rubble removal project to achieve this target. The significance of the rubble removal project extends beyond the removal of debris. While the project may have accomplished the short-term relief objective, it also influenced the long-term development goal towards sustainable living. This paper examines the project's impact on livelihoods in Gaza. It demonstrates the significant role of partnership and the use of the appropriate low technology in building the local capacity necessary to achieve sustainable livelihoods. It argues that, despite the Israeli blockade, a comprehensive development in Gaza may be possible through partnership and mobilization of local resources. The paper concludes with a set of guidelines towards the adoption and successful implementation of community-driven initiatives in Gaza.

15.1 Sustainable Livelihoods: Partnership and Appropriate Technology

Sustainable development traditionally encompasses socio-economic and infrastructure, governance and environmental dimensions. It addresses the balance of social, economic, environmental, cultural and spiritual values in the long-term on a holistic and cumulative level (Margolus et al. 2011; Hassan and Zetter 2002). In an

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extremely fragmented and downgraded post-conflict context, reducing the level of vulnerability to social, economic, and environmental shocks should be a prime concern of any development and reconstruction approach. Grainger (2004) argues that at the household level, the prime concern is with the sustainability of livelihoods rather than with the sustainability of development as a whole. Therefore, if sustainable development is to advance the living environment, the corner stone for success should be its effect on the livelihoods of poor and vulnerable groups.

The livelihoods approach to reconstruction and poverty reduction stresses the primacy of the role of local community and the need for the mobilization of the resources of a revitalized society to fill the gap in development needs. It transcends the rather limited economic view of human welfare to address the ‘local’ capabilities and assets. The role of the locality is pivotal in achieving successful reconstruction and the wider objective of sustainable livelihoods (Selman 1996). The notion of locality is twofold: physical and social.

The *physical dimension* refers to a place and the local people, and to the administrative system that controls various activities. In other words, a locality offers an exclusive environment with a set of resources (including both material and human resources) and a wealth of experiences (local knowledge), and subsequently a locally based technology: Appropriate Technology (AT).

In a post-conflict reconstruction context, AT offers a grass-roots alternative approach to technology and development. This is an approach which is energy-efficient, environmentally sound and labor-intensive, with many terms used to describe it, such as low to intermediate, progressive, alternative, light-capital, low-cost and indigenous (Vergragt 2006). It is argued that AT essentially contributes to sustainable development in terms of the provision of basic needs and also the supply of dignified work (Zelenika and Pearce 2011). This is significant especially in the aftermath of conflict, where deprivation of basic needs prevails and access to resources is constrained, as is the case in Gaza.

The *social dimension* of a locality refers to groups and individuals who are associated through a network of shared responsibilities, cultures or interests. It underpins the discourse of partnership and the efforts to mobilize the local community members to enhance the development and reconstruction process. While there is a wealth of experience with public–private sector partnership, it was not until the 1990s when a more broad based partnerships have emerged in forms that extend to the civil society, including community organizations and representatives of people living in poverty (Barakat and Chard 2010; UN-Habitat 2003). Bowen (2007) explains that partnership brings a diverse range of stakeholders’ contributions in an ongoing community development process starting with the identification of the problem and ending with the implementation and management. These forms of tri-sector partnerships (private–public-society) can bring about a transformation in opportunities for better livelihoods for poor and devastated communities including: reduction in conflict; efficiency; diffusion of responsibilities; and the exchange of experiences and knowledge. Although there are still several questions that should be addressed—including the debate over political accountability, the complex process of consultation and coordination, and inequality—working in partnership can still promote transparency, build confidence among partners, and allow shared responsibilities.

Accordingly, locality provides a spatial dynamics that serves as a theater of human interactions as well as a reflection of the social relations. While achieving the sustainable livelihoods objective is determined by this spatial dynamics (locality), it is also contingent on the available technology as well as on the capacity to establish successful partnerships. Bearing in mind the scale of physical destruction, limited access to resources, widespread of poverty, and loss of assets in the aftermath of the conflict, as in the case of Gaza, the role of AT and partnership becomes significant. The following sections will highlight the context of Gaza, development stakeholders and project mechanism. They will assess the impact of the project and the capacity of partnership and AT to contribute to the long-term capacity development objective.

15.2 Context

Since 1948, a continuous cycle of violence has dominated the scene in Gaza and created an unsettled environment that has hampered the development process. Beall and Fox (2009) argue that in contrast to old wars, where fighting was governed by respected rules that protected the civilians, the new wars intend to generate fear, destabilize the socio-economic structure, and displace people. Urban livelihood in the Gaza Strip is no exception. It has been negatively affected by the recent armed conflict. This has been reflected, as explained below, in the physical, socio-economic and political/institutional aspects of life.

As a result of the military operations, the built environment suffered a large share of destruction in terms of damage to buildings, the road network and the infrastructure (MoP 2009). Residential buildings provide a good example of the wide-scale physical destruction. While Gaza is one of the most populated areas in the world, with population density of 4,384 persons per square kilometer, approximately 22 % of the housing stock was affected and almost half of it became uninhabitable (Barakat et al. 2009). As a result, more than 26,000 people became homeless and 75,000 people were either displaced or living in very difficult conditions (PNA 2009).

Environmentally, Gaza has suffered several kinds of pollutants including: a huge amount of debris and rubbles, uncollected solid waste, air pollution, and sewage overflow—due to the destroyed network (UNEP 2009). The growing demands on the limited local resources especially potable water, are another unsustainable practice. Soil contamination with heavy metals and the discovery of asbestos in the rubble of destroyed buildings are further evidence of the serious environmental conditions.

From a socio–economic perspective, siege, loss of local businesses and job opportunities, termination of day-labor permits to enter Israel, and irregular salary payments for the government employees, have all contributed to the deteriorating economic conditions and affordability per household. The assault, sanctions system and siege, have resulted in the virtual collapse of Gaza's private sector and a deterioration in educational and health services. The Israeli government allowed no more than 25 % of the needed food supplies. While poverty level in Gaza was approximately 56 % in 2007 prior to the conflict, it witnessed a notable increase and reached between 80 and 85 % under the poverty line with an increase in unemployment rates to 60 % in the post-conflict period to 2009. According to Saleh (2011) the total consumption of the Palestinian Authority in the West Bank and Gaza exceeded the GDP and stood around 139 % of the GDP in 2008–2009. This points out to a serious gap between income levels and the level of spending. It also indicates the lack of ability to save, with domestic savings reaching a negative 39.4 % in the same year.

Additionally, due to the lack of job opportunities, highly skilled workers started to compete for low-skilled job opportunities, leading to growing unemployment among the low-skilled labor force (Mansour 2010). Moreover, the relatively easy access to cash benefits and welfare support encouraged dependency and a reluctance to seek job opportunities, leading to growth in voluntary unemployment (Abu-Rass 2011; PCBS 2012). This partly explains the deterioration in individual skills and institutional capacities.

Government/institutional capacity was one of the main targets of this conflict, with the aim to undermine the Hamas government and reduce its capacity to deliver adequate levels of services and support. Therefore, many governmental buildings were targeted during the conflict, staff were seriously injured or killed, and documents and equipment were destroyed.

The above presentation demonstrates the dark scene of the post-conflict context. It underlines the need for an integrated perspective to improve livelihoods and to stop the cycle of deterioration in Gaza. While access to external support is restricted, attention should be focused on the local resources and capacities for development. This provides a departure point for the rubble removal project that will be discussed in the following sections.

15.3 Research Methodology

The main objective of this research is to explore the interplay between partnership and the appropriate technology poverty alleviation approach in a post-conflict context towards sustainable livelihoods. The rubble removal project, in the unique context of Gaza, provides an excellent opportunity to investigate these links. It demonstrates the role of the stakeholders in mobilizing the local resources and capabilities towards poverty reduction and capacity development.

This paper is based on fieldwork conducted in Gaza between September and November 2011. Using a qualitative dominant approach, primary data were collected through interviews with key informants and a project survey using a questionnaire. These were conducted with stakeholders of the rubble removal project (community members, project officers, trained engineers, and contractors), and professional staff in government agencies responsible for planning, housing and infrastructure; non-governmental agencies; and donors.

15.4 Rubble Removal Project Setting; Partners and Contributions

15.4.1 Development Approach

The development approach of this project attempts to utilize the local resources and capabilities to improve the livelihoods of the devastated communities through a collaborative process of remove-recycle-reuse of the rubble using AT. Building capacities through partnership provided the cornerstone for this process.

In order to facilitate this approach, several measures were adopted, including: capacity building and training programs, job creation programs, and direct compensation. The diversity of measures provided, the more flexible approach required in a post-conflict context. While rapid intervention using financial assistance is a short-term relief objective, training programs supported the longer-term objective of capacity development. Training is an essential component in order to prepare the local stakeholders to become familiar with low technology techniques and supervision, and to understand the risks involved in dealing with the rubble in the aftermath of the war.

15.4.2 Project Preparation and Design

Following the preparation of the Gaza Reconstruction and Development Plan (2009) and the Conference in Support of the Palestinian Economy for the Reconstruction of Gaza in Sharm El-Sheikh in March 2009, the Ministry of Public Works and Housing (MPWH) invited local and international partners to participate in the design of the rubble removal process in Gaza. The project offered an urgent relief and a kick-start for other reconstruction activities (Table 15.1). After a series of meetings and discussions, it was agreed that the MPWH would coordinate the project activities, supply equipment and data records needed for the project implementation and deal with the rubble removal of a limited number of public buildings in collaboration with other partners. Meanwhile international agencies and donors led by the United Nations Development Programme (UNDP), would lead the implementation of the rubble removal process in collaboration with local contractors, trained engineers, and community members.

Despite the coordination role of the MPWH, funding has not been channeled through the local government. While major donors, such as the Canadian

Table 15.1 Rubble removal project description

Project title	Post-conflict rubble removal project	
Main objective(s)	Removing the rubble of 2,106 residential buildings and 95 government buildings and mosques	
Location	Gaza Governorates and Camps	
Responsible agency	Ministry of Public Works and Housing (MPWH)	
Donors	Canadian International Development Agency (CIDA), Swedish International Development Cooperation Agency (SIDA), Japanese Government, Islamic Relief (IR)	
Partners	*External:* United Nations Development Program (UNDP), Kuwaiti Mercy, Islamic Relief (IR), UN Relief & Work Agency (UNRWA), Cooperative Housing Foundation (CHF), Norwegian Refugee Council (NRC)	*Internal*: Ministry of Public Works & Housing (MPWH), Mine Action Group (MAG) - (NGO), Qualified Palestinian Contractors, Volunteered engineers, citizens
Budget	US$ 12 million (estimated)	
Starting/ End date	July 2009–March 2011	
Project stages	Demolition, classification of rubble components, crushing and recycling or reuse	

International Development Agency (CIDA) and the Swedish International Development Cooperation Agency (SIDA), channeled their funds through the UNDP, other partners used their own sources to raise the necessary funds for the project implementation. The role of the local counterpart, the MPWH, has been largely marginalized in monitoring the flow of external funding and contracting because, on the one hand, the local government led by Hamas, has not been internationally recognized, and on the other because of the political division and competition between the Palestinian Authority in the West Bank and the Hamas government in Gaza.

Due to the large scale of this project and the dispersal of the affected buildings over a large geographical area, it was not possible for a single partner to take the responsibility for the whole project. Subsequently, the task was divided between partners according to their capacities, funding priorities and experiences (Fig. 15.1). Meanwhile, the private sector, represented by the local contractors and suppliers, led the implementation on the ground. The remaining part of this section will describe the main role of each participant in the removal process including: UNDP, United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA), Norwegian Refugee Council (NRC), Cooperative Housing Foundation (CHF), Islamic Relief (IR), Kuwaiti Mercy, and Mine Action Group (MAG).

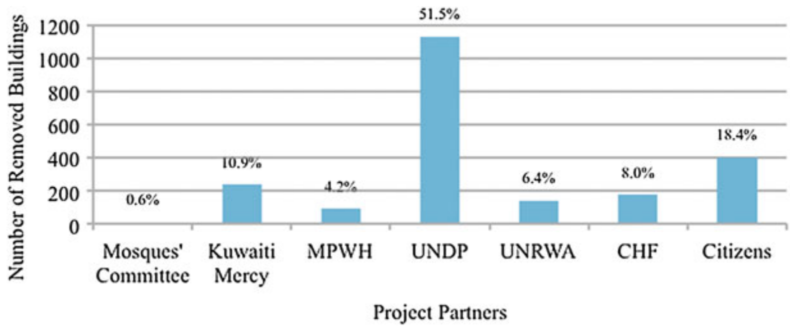

Fig. 15.1 Number and percentage of buildings removed by each of the project partners

Building on its experience in rubble removal of the demolished ex-Israeli settlements in Gaza, *UNDP* was assigned the majority of the damaged building sites all over Gaza Strip. The allocated fund made it possible for UNDP to reach almost everywhere in Gaza. The UNDP strategic plan to improve the livelihoods in Palestine provided guidance for the project design and implementation for the UNDP as well as other international partners, as explained below. It aims to achieve economic development through empowerment and the use of a bottom-up approach (UNDP/PAPP 2008 & 2010). According to this approach, capacity development and AT, as well as partnership with the local community, are key components of project design towards sustainable livelihoods. These components will be discussed in detail in the following section.

A team from *MAG*, a local non-governmental organization (NGO), in collaboration with UNDP, was assigned to secure the project sites and to ensure that these were explosive-free. The team received professional training through the capacity-building component of the UNDP project. MAG discovered more than 300 unexploded ordnance (UXO) and explosive items and 2,100 small-arms ammunition in different sites using some basic tools (UNDP 2011a). Figure 15.2 shows the role of each partner in this project.

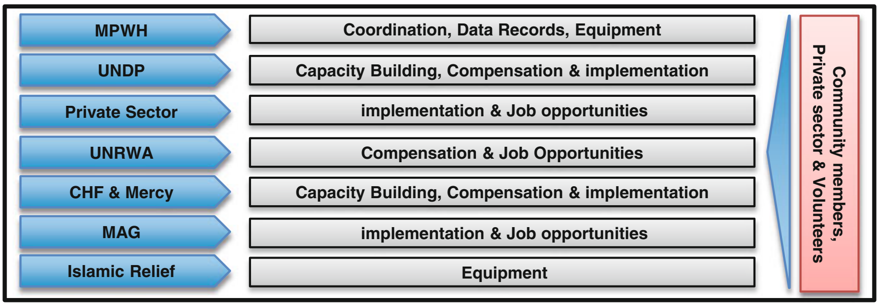

Fig. 15.2 Partners' contributions in the project to improving Gazans' livelihoods

For *UNRWA*, the rubble removal project was a component of a wider development project that aimed at enhancing the local capabilities of skilled and non-skilled labor and university graduates. The project was designed in close coordination with members of the Gaza Shelter Cluster and Reconstruction Working Group, notably UNDP, NRC, CHF and MPWH (UNRWA 2009). The project offered full compensation for the owners of the damaged buildings. This measure allowed homeowners to hire local contractors to remove the rubble. It helped to alleviate the impacts of rising poverty and unemployment amongst refugees within the Gaza Strip.

Kuwaiti Mercy Corporation for Development and Relief focused on the rubble removal of a few public buildings and houses that threatened the public, and also offered compensation for the owners of damaged properties to rebuild their homes as well. The NGO paid attention to two tangible issues throughout the project: capacity building and public involvement (Hammad Interview 2011). The development vision of Mercy promoted the public engagement in all project stages: design, implementation, and operation and the successful integration of the available technology.

The Cooperative Housing Foundation (CHF) provided both financial compensation and training for the owners of the damaged houses through the job creation scheme (Aburayya Interview 2011). Meanwhile the UK-based NGO *Islamic Relief* (IR) provided support for the local municipalities. IR funded the provision of labor and machinery which were needed for the rubble removal of the public buildings. However, the contribution of both CHF and IR was constrained by the Israeli blockade.

Due to the relative shortage of equipment and local contractors, and following the training of the local community members on rubble removal, approximately 400 owners of destroyed buildings took the initiative to remove the rubble of their destroyed buildings by themselves (Albohaisi Interview 2011; Alrouby Interview 2011). While removing the rubble speeded up the process of reconstruction and restored the living environment of the displaced families, selling the removed rubble offered an additional source of income that contributed to the poverty alleviation objective.

The project, as explained above, provides an umbrella, which hosts various international and local partners, and is coordinated by the MPWH. Although the local government is not internationally recognized, on the ground the imperatives of locality indicate that the coordination role of the MPWH is unavoidable and necessary for the success of the project. It also demonstrates that siege provides a unique environment and poses additional challenges to the already complex post-conflict reconstruction context of Gaza. It leaves no option but to rely on local capacities and resources through partnership and available technology to restore the living environment. This will be discussed in the following section.

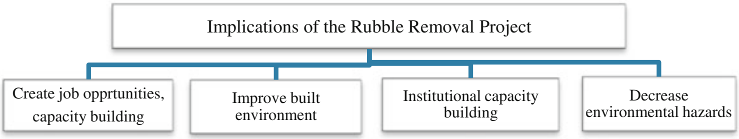

Fig. 15.3 Implications of the rubble removal project

15.5 Partnership and Appropriate Technology: Have These Reduced Poverty and Improved Gazans' Livelihoods?

Partnership requires identifying the existing and potential roles of various stakeholders, including the poor and vulnerable, local authorities, private sector and civil society groups, as well as the international community. The main goal, as explained above, is to combine the strengths of stakeholder groups to maximize their contribution towards the short-term rubble removal objective and the long-term sustainable living and poverty reduction objective (Fig. 15.3). The extent to which these objectives have been met, underlines the success or the failure of the partnership process. The answer to this query may be achieved by considering the interplay between the poverty reduction approach, participation, and technology as is discussed below.

Local and international agencies involved in this project adopted a dual approach to poverty reduction that combines welfare provision and self-determined solutions. The welfare orientation offers services and pays for improved housing and rubble removal. NGOs, such as Mercy, CHF, MAG, and IR led such approaches where they offered services with no measures for cost recovery. While this provision in the aftermath of the war is important to achieve a rapid and positive impact on the quality of life for the mass poor population, it is not attractive because it carries the risk of promoting dependency on external funding and sources. Therefore, the self-determination solutions were incorporated to complement the dual approach.

Self-determination solutions reduce the likelihood of dependency by advocating partnership through autonomous actions that combine community and local authorities, international agencies and local NGOs. The project design recognized the value of using the rubble removal process as a means of mobilizing the local resources and capacities, and utilized the available technology to alleviate poverty in the longer term.

The training and capacity-building component offered by the UNDP, Mercy and CHF was necessary to improve the skills and capacities of government staff, volunteers, owners of damaged buildings, and contractors. It also promoted a sense of solidarity within the locality towards the common goal of relief. This has been evident in the case of damaged mosques. In a self-motivated initiative, community members and contractors had partnered to form a mosque committee (MPWH

2011). Members of this committee applied their training and practical experiences of damaged houses to remove the rubble of the impacted mosques in various neighborhoods. The importance of this example lies in the capacity of the local community to organize itself and utilize its capabilities and acquired skills, as well as the available low technology in a successful partnership towards a common good without access to external resources.

Another example was recorded during the rubble removal process. As a result of the shortage of contractors to carry out the removal task in a due course, trained homeowners and members of their families partnered together to remove the rubble of their damaged houses. Using low technology and the credit allocated for rubble removal and rebuilding damaged houses, homeowners or members of their families cooperated with and worked for each other in order to speed the process of rubble removal. While this provided an income generation opportunity that would help to improve their living conditions, it also offered job opportunities for the unemployed community members as well as a chance to develop future career in construction.

The self-determination solutions of this project were not limited to the mobilization of human skills and the organizational capacities of Gazans to improve their living environment. Rubble was regarded as a source of income generation rather than a problem. The selling, recycling and reuse of the recovered products provided additional income and job opportunities, and safeguarded the local environment in a sustainable fashion. Studies indicate that approximately 22 % of the homes with major damage have been repaired using recycled and reused products such as iron, wood, plastics, aluminum and glass. In addition, the removal and crushing of concrete rubble generated more than 150,000 job opportunities and provided more than 56,000 working days which contributed to poverty reduction efforts (ElKharouby 2011).

The use of appropriate low technology, as discussed above, is the backbone of the self-determination solutions of this project. While Gazans had limited access to intermediate and advanced technology, contractors and homeowners used basic tools including hoes, rakes and pickaxe for processing rubble *in situ* (UNDP/PAPP 2010). They used a limited number of jackhammers, excavators, cutting equipment, cranes, bulldozers and trucks. Bearing in mind the high amount of low-skilled labor, the high levels of poverty and unemployment, as well as the fact that 13.9 % of the total labor force in the Palestinian Territories work in the construction industry (PCBS 2012), the adoption of the available labor-intensive technology helped to create a large number of job opportunities and mobilize the human resources. This again fed into the efforts to combat poverty and to improve the lifestyle.

Furthermore, AT proved to be cost-efficient in the current situation in Gaza. The cost of demolition, transporting and crushing one ton of concrete rubble does not exceed US$ 10.50, while the cost of one ton of natural crushed aggregate exported from outside Gaza is US$ 15.38. Also, the sale price for crushed concrete rubble, which is used in road construction is nearly US$ 7.50 per ton compared to more than US$ 30 per ton (ElKharouby 2011).

The above presentation reflects the interaction between the poverty reduction approach, partnership and available technology. It advocates the capacity of partnership and low technology to positively contribute to the livelihoods of the mass poor people in the aftermath of the war. While mobilization of the local capacities and resources is a corner stone for sustainable livelihoods, training and capacity development programs facilitate this process and open up a new horizon for the local community members to independently improve their livelihoods.

In a war-torn society, the capacity of the community members to get organized and replicate the gained experiences independently is another key lesson in this project. It shows that poverty and development constraints do not stop the local desire to improve livelihoods. It also points to the fact that welfare assistance and benefits approach to tackling poverty and deprivation, may maintain a baseline of economic welfare and recovery from shocks but it does not guarantee reduced poverty. Therefore, greater emphasis, should be placed on self-dependent solutions to mobilize the local capabilities and assets for development.

15.6 Conclusion

There is no universal solution to achieve sustainable livelihoods and poverty reduction. Therefore, efforts to achieve this objective should pay great attention to the spatial dynamics that constitute the locality. The significance of the locality is that it offers a better understanding of the local resources, capacities and the social network that are necessary to build a meaningful partnership and utilize the available technology.

Often, in a post-conflict context, government agencies lack sufficient resources to offer the most needed support for reconstruction and poverty alleviation. In the case of Gaza, partnership played a main role—on the one hand to scale down the responsibilities of the local government, and on the other to place more emphasis on capturing the resources of the donors, private sector and civil society. While there is a tendency to call any initiatives that involves more than one sector a partnership, the case of the rubble removal project provides authentic partnerships that build skills, create new social relationships and empower the weakest segments in the society towards sustainable living.

The case in Gaza indicates that the use of the appropriate technology proves cost-efficient. In a community which is dominated by unemployment and lack of professional skills, the use of the available basic technology opens up the door for a wider participation and mobilization of human resources. AT—with its emphasis on the use of local materials, low capital costs, collective rather than individual efforts, and economic self-dependency,—seems successful in the aftermath of the war and ban on building materials and technology. However, it should be noted that AT has its own limitations and it cannot solve national economic problems on a longer term. Therefore, a balance between appropriate low and high technology is essential to close the gap in technology. This may require a political break through to remove the blockade, ensure the free flow of people and goods, and sustain development efforts.

Finally, given the existing weaknesses and the political, social and economic instability, a long-term objective of sustainable livelihoods implies building on what is there, without expecting a major transformation. It also entails that external agencies should be influenced by priorities of locality and those who face deprivation and build on their knowledge and resources.

Interviewees

Name	Position
Aburayya, Y.	Cooperative Housing Foundation Officer
Alouby, A.	Engineer and owner of a damaged property, the citizens' contribution of rubble removal project, Gaza City
Albohaisi, S.	Director of Arab and International Cooperation Department, Ministry of Public Works and Housing—MPWH contribution of rubble removal project, Gaza City
Hammad, M.	Mercy Corporation for Development and Relief Officer, Gaza City
Shawa, N.	Information Management Officer, Communications Focal Point, UNDP/PAPP, Gaza Office—UNDP contribution in rubble removal project, Gaza City
Elhussaini, E.	UNDP Manager, Gaza City

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Chapter 16
Integrated Design Charrettes for Sustainable Development in India's Soaring Building Sector

Pierre Jaboyedoff, Kira Cusack, Sameer Maithel, Kanagaraj Ganeshan, Saswati Chetia and Prashant Bhanware

Abstract During the last 15 years, the sustained economic growth in India has generated considerable increases in energy demand. Moreover, while the building sector already accounts for 33 % of the country's electricitydemand, and while the building stock is expected to increase twofold at least by 2030, the issue of energy efficiency in buildings becomes a matter of primary concern for the nation's continued social and economic development. In an attempt to respond to this challenge and to contribute to reducing energy consumption in new buildings, an agreement was signed between the Swiss and Indian governments to launch a bilateral cooperation program entitled the Indo–Swiss Building Energy Efficiency Programme (BEEP). One of the main components of this program consists in performing and promoting the practice of *Integrated Design Charrettes* for large commercial building projects. *Integrated Design Charrettes* appear to be an adapted mechanism to bring about change in building practices in India at a time when the Indian building sector is undergoing unprecedented growth, which presents considerable challenges for energy demand management and sustainable development. The objectives are twofold, first, to create best practices in India's large commercial building projects and second to build the capacity of Indian practitioners to develop energy efficient and climate responsive building concepts.

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16.1 Introduction

The Indo–Swiss Building Energy Efficiency Programme (BEEP) is a bilateral cooperation program, which is supported by the Swiss Agency for Development and Cooperation (SDC) under the Global Programme for Climate Change (GPCC). The program aims at assisting India in increasing the energy efficiency of its new building stock. This paper focuses on one aspect of this program, namely the *Integrated Design Charrettes*, and explains how the concept was developed to address the needs for increased energy efficiency in India's soaring building sector.

16.2 The Indian Context

16.2.1 India's Energy Scenario

India already ranks fifth worldwide in terms of primary energy demand (Dessus et al. 2011), and the energy demand continues to grow alongside India's rising economy. According to the Planning Commission, if the current growth rate of 8 % per annum is sustained, the country's electricity generation capacity will need to be multiplied by five or six by 2031 (Kumar et al. 2010). Core sectors of the economy are creating important demand that India's Central Electricity Authority (CEA) struggles to meet.

Meanwhile, India relies on coal for 75 % of its electricity production, which generates two-thirds of India's Green House Gas Emissions (Friedman and Schaffer 2009). The country's CO_2 emissions reached as much as 1.4 million tons in 2008 (Dessus et al. 2011).

Although over 70 % of India's population resides in rural areas, Indian cities are already home to 340 million people, and estimations indicate that the urban population will reach as much as 590 million by 2030 (Shirish and Dobbs 2010). This represents the fastest addition to an urban population of any country in history outside China.

16.2.2 India's Building Sector

As a result, the national building market is undergoing unprecedented growth. The Indian construction sector, second largest employment provider in the country is currently growing by 8 % per year. If the building sector grows by no less than 3 % until 2050, India's built-up area will increase twofold between 2005 and 2030. This would represent an addition of 8 billion square meters of new buildings, as much a twice the current German building stock, as illustrated in Fig. 16.1. This would imply that an average of 500 million m^2 would be built every year between 2010 and 2050.

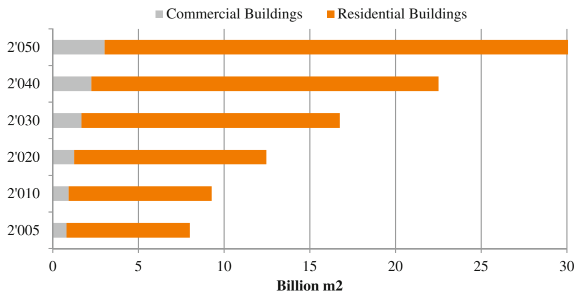

Fig. 16.1 Estimation of the Indian building stock until 2050

16.2.3 Energy Demand

The building sector currently accounts for 37 % of India's energy consumption and as much as 33 % of India's electricity consumption. Electricity use in commercial and residential buildings has been increasing more rapidly than in other sectors of the economy. Since 2000, electricity consumption in the residential and commercial sectors has doubled, as shown in Fig. 16.2.

India has five climatic zones across the country. With the exception of the cold climate found in the Northern Himalayan region, all of India's climates are characterized by long cooling seasons, which include longer or shorter monsoon seasons. As a consequence, cooling constitutes the larger share of energy required for buildings, and the key concern for designers is to manage solar gains.

To address these challenges, the Government of India created the Energy Conservation Building Code (ECBC) in 2007 which applies to large commercial buildings on a voluntary basis. However, the country still lacks an effective legislative system to enforce energy efficiency measures for new buildings. In addition, building professionals and practitioners tend to lack the practical knowledge and awareness to design climate responsive and energy efficient buildings.

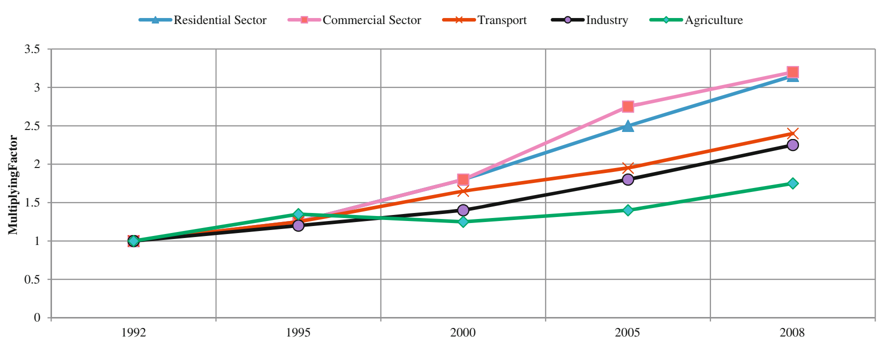

Fig. 16.2 Increase in final electricity consumption per sector since 1992

16.2.4 The Building Energy Efficiency Programme (BEEP)

BEEP was proposed by SDC, Sorane SA and Greentech Knowledge Solutions Ltd. to the Bureau of Energy Efficiency (BEE) of the Indian Ministry of Power in 2008. After some iterations, the program was accepted and an agreement was signed between the two governments to jointly implement the program from 2012 to 2016. The program included 24 *Integrated Design Charrettes* to be conducted in relation to large commercial building projects, starting in October 2012. The *Charrettes* were to be facilitated by an Indo–Swiss Project Management Unit comprised of senior engineers, energy consultants and project managers from Greentech Knowldege Solutions for India and Sorane for Switzerland.

Sorane SA is recognized as one of the leading energy saving engineering companies in Europe specialized in renewable energies, energy efficient building design, as well as optimization and energy retrofitting. The company was created in 1977 following the first oil crisis to carry out applied research and experiment solutions to drastically reduce energy consumption in buildings. Following some assignments for the International Energy Agency (IEA), the company developed substantially to reach the number of 23 highly qualified employees today. Sorane's clients include major Swiss companies such as Migros, Rolex and Nestlé. Sorane is also the technical implementing agency for the Swiss Federal Office for Energy Programme, Energo, which focuses on public and semi-private buildings with a view of saving 10–15 % of their energy consumption through optimization of Heating Ventilation and Air Conditioning (HVAC) Control.

Greentech Knowledge Solutions Ltd. is a New Delhi-based consultancy firm, specialized in energy efficiency and renewable energy solutions in buildings, urban and rural communities and small industries. Greentech Knowledge Solutions provides consulting services in the area of building energy efficiency, decentralized renewable energy applications, energy efficiency in small enterprises, solar water heating applications and capacity building.

SDC is represented in India by the Climate Change and Development Division (CCD) of the Embassy of Switzerland. CCD is responsible for the execution of operational programs in the field of climate mitigation and adaptation. CCD works mainly through a multi-stakeholder set-up with Indian and Swiss institutions and organizations. It also involves national and international experts in the conceptualization, design, planning, implementation and review of the relevant thematic programs.

16.3 *Integrated Design Charrettes*

16.3.1 Rationale

The key rationale for carrying out *Integrated Design Charrettes* in the Indian context is to tap the largest energy saving potential at minimal cost. Research has shown that the energy saving potential of a building is at its highest point at the

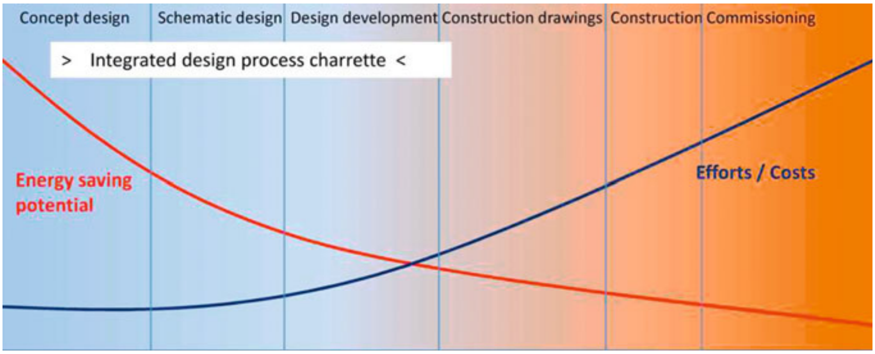

Fig. 16.3 Relationship between energy saving potential and costs in a building design process

onset of the project. As the design proceeds and decisions are frozen, the energy saving potential is reduced, while the cost of tapping it is increased. Figure 16.3 illustrates the relationship between the energy saving potential and the cost of energy saving measures throughout the project design.

Integrated Design Charrettes consist of a three-day interactive workshop which brings together the whole design team with two to four senior experts to develop the energy concept of the project. The know-how and experience is provided on the spot (through the presence of highly experienced experts) to allow participants to address the project in a holistic manner while integrating energy efficiency as a primary goal.

Typically, on the building project side, the participants will include at least the client, the developer, the architect, the landscape architect and the Heating Ventilation and Air Conditioning (HVAC) engineer(s), while the expert team is composed of two to four highly qualified Swiss and Indian architects and engineers. During the *Integrated Design Charrettes*, the participants will review the building design in a systematic way. The participants may propose various strategies to address the project functions. The strategies proposed will normally reflect their insights and support specific functions. In this way, the interactions between the different solutions can be addressed and the implications weighed against one another. This process is considerably timesaving and cost-effective.

Figure 16.4 illustrates the interactions between different strategies for energy saving in a building project. The combination of strategies for (i) reducing unwanted solar gains, (ii) minimizing internal gains through promotion of daylighting, (iii) promotion of natural ventilation, (iv) implementation of mechanical ventilation with heat recovery for indoor air quality, (v) highly efficient active systems as well as (vi) on-site renewable energy production and supply allows for the design of a near zero building.

Integrated Design Charrettes make it possible to identify optimal solutions by addressing the key building functions in a systematic and multidisciplinary way.

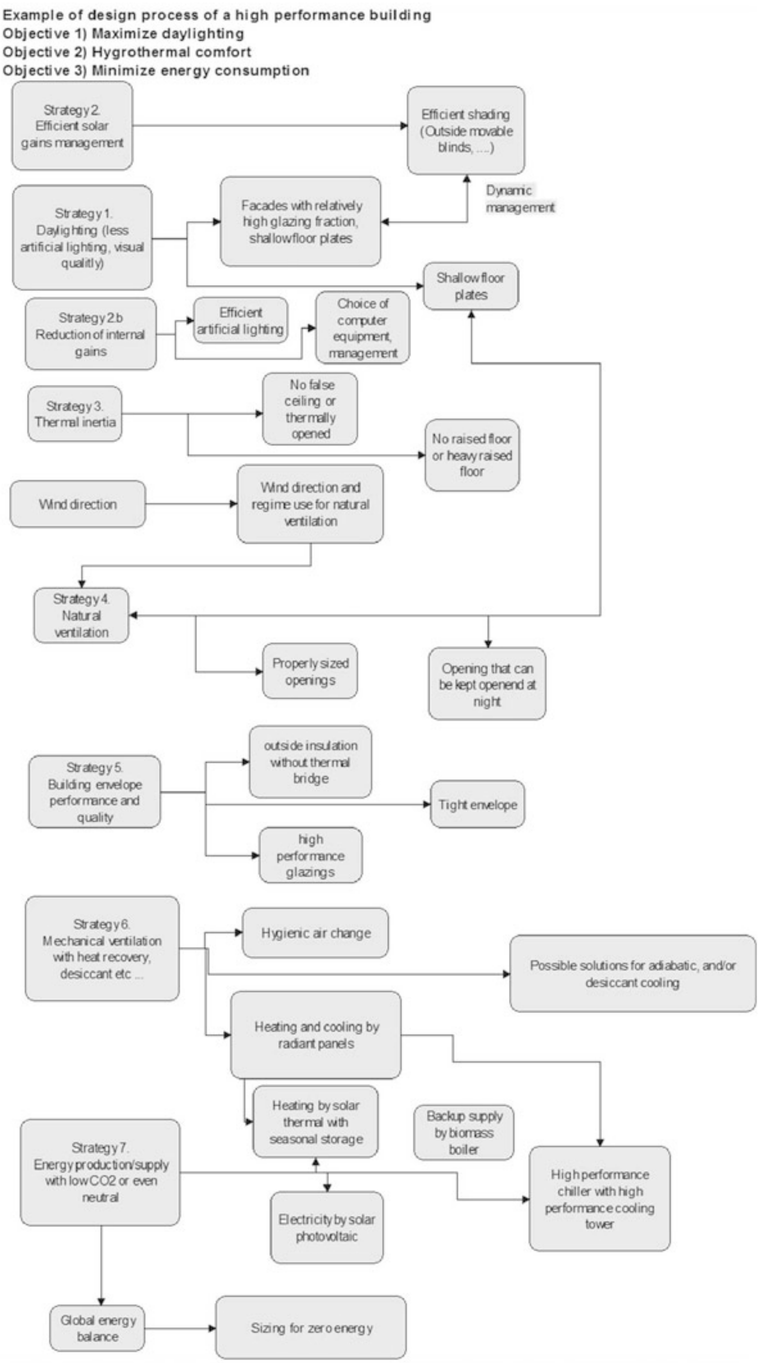

Fig. 16.4 Interactions between different energy efficiency strategies on a given building project

International experience has shown that the building design concept should first focus on reducing energy demand to a minimum, following which systems design can aim at optimization and increased efficiency through advanced technologies. This approach will be used for conducting the *Integrated Design Charrettes.*

The *Integrated Design Charrettes* will comprise several working sessions, during which the participants may be divided into smaller groups if some issues require further iterations. During the workshops, and during the follow-up, the expert team will carry out dynamic energy simulations, using advanced simulation tools such as TRNSYS and Energy Plus to estimate the energy saving potential of the strategies proposed. The models will have been prepared beforehand to allow for quicker assessments during the workshop. In some cases, parametric studies may be conducted using a “generator”. This specific tool was developed by Sorane over the last twenty years under Excel and Visual Basic, in order to test a series of different individual and combined solutions in building projects. Sorane’s generator allows the user to change a number of selected variables in the source files and carry out automatically a series of runs with TRNSYS. Results may be retrieved rapidly and are imported in the same file to allow for comparative analysis. In this way, the user can sequence-test different solutions in order to develop an optimal solution. Figure 16.5 gives an example of a model developed for an Indian building, using TRNSYS energy and systems simulation tool. The model was first developed, and then used with Sorane’s generator to carry out a parametric study.

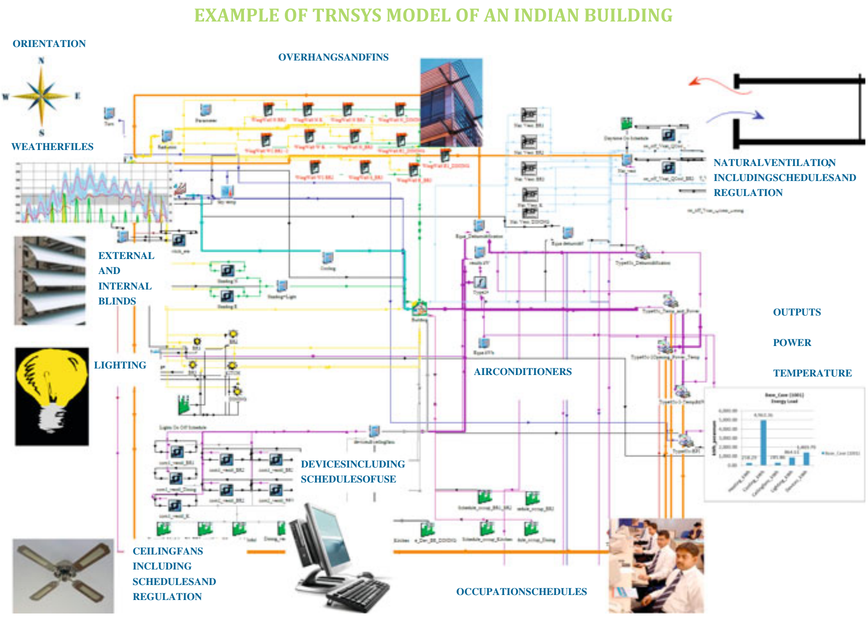

Fig. 16.5 Example of TRNSYS model developed for a building project in India

Advanced energy and system simulation tools are rarely used by engineers and architects in India because of their complexity and because of the time investment needed to master them. The workshops will offer the opportunity to demonstrate the results which can be achieved and to raise the awareness of Indian professionals on the benefits for the design process of using these tools. Training and capacity building on the use of advanced simulation tools in building design will be carried out alongside the *Charrettes*, within the framework of BEEP.

During the *Integrated Design Charrettes*, the expert team will also carry out rapid cost assessments in relation to the strategies proposed. For this purpose, BEEP has created a specific tool, the Cost and Supplier Database. The tool was developed considering the need for developers to have cost estimates to make design choices during the *Charrettes*. Moreover, up-to-date prices of these rapidly-evolving technologies were found to be difficult to source. Figure 16.6 is an example of the data available for blinds and louvers.

Each project may have different timelines and procedures, and the design may be amended after the concept design for a number of reasons. Therefore, after the three-day workshop, the project will offer continued support for a period of approximately 6 months. The expert team will provide technical support to review and reassess the design. If need be, specific working sessions will be organized with the relevant stakeholders.

Once the final design is completed, a meeting with the design team will be organized to validate the final design, evaluate the savings achieved by the final project compared to the baseline (the initial project) and prepare the case study documentation if relevant. In this way, the *Charrette* partners are encouraged to

B	C	D	F	G
Component	***Vendor/ Manufacturer Information***	***Brief Description and specification of strategy/ technology***	***Cost Detail [Rs/m²]***	
			Max	***Min***
Screenline Solar PV Blinds		Solar PV operated	17'216	
Lutron Motorized blinds	Lutron	Motorised control blinds,programable with daylight sensors and software of lutron (Cost of fabric plus the cost of motorwhich is 60,000)	62'152	
Hunter Douglas Louvers	HUNTER DOUGLAS INDIA ltd. Mr. A. M. L. Reddy Mobile:- 88022286364	External aluminium blinds and light transmission can be controlled by adjusting the angles of slats	11'298	5'800
Indus Louvers Screen 50	Indus Louvers Mr.Kapil Sharma M:-9818876625	Screen50	8'070	6'360
Indus Louvers Screen 75		Screen75	8'070	6'360

laster List | 1.1 Wall | 1.2 Roof | 1.3 Insulation | 1.4.1 Glass | 1.4.2 Framing | 1.4.3 Blinds | 2.1 Syste

Fig. 16.6 Cost and supplier database of energy efficient solutions and technologies take part in knowledge exchange and dissemination with a view to increasing awareness on best practices in India and promoting energy efficient building design by and large in India.

Initially, the *Integrated Design Charrettes* have been proposed to large public and private builders and developers for assisting in the design of large commercial buildings. The impact in terms of absolute amounts of energy saved is expected to be more important for such buildings than for smaller scale buildings. Further, by focusing on India's prominent private stakeholders on the one hand, and on public authorities on the other, the aim is to contribute to integrating energy efficient practices in the mainstream.

The principle of holding some 24 *Integrated Design Charrettes* in the five coming years is to contribute to creating a "culture of energy efficiency" among the builder and developer community and to build the capacity of building professionals to design energy efficient, climate-responsive, high performance buildings. The assumption is that each *Integrated Design Charrette* will have a strong replication effect, and that eventually the practices will be streamlined.

16.4 Status and Timeline

As of today, the first four developers have been selected following the publication of a call for expressions of interest in June 2012. The first two *Charrettes* were held in the fourth quarter of 2012. First lessons learned indicate that the developer community is keen to adopt the *Integrated Design Charrette* approach. The three main strong points appear to be (i) that the interdisciplinary approach allows to achieve design with short timelines, (ii) that dynamic energy and system simulation allows for fast assessment and informed decision-making, and (iii) that practical experience and knowledge of energy efficient strategies is needed at the early design stage.

16.5 Expected Results

The *Integrated Design Charrettes* are specifically designed to promote an interdisciplinary approach in energy efficient building projects. They artificially create the opportunity to confront and harmonize the strategies proposed and the functions required by the building project. In the Indian context and within the framework of BEEP, the interdisciplinary approach is encouraged at the project outset with the specific aim of bringing forth issues related to energy efficiency. The objective is to assess the impact of design choices on the operational energy which will ultimately be consumed by the building(s), and to encourage effective strategies in that respect. Often, this will entail reducing solar gains to a minimum while making sure that the quality of daylight is sufficient, as the largest part of India has hot/dry or hot/humid climates. The *Integrated Design Charrettes* will obviously bring about other issues, such as comfort, water resource management, embodied energy, indoor air quality, biodiversity conservation and the like. Nonetheless, most of these concerns can be addressed through the spectrum of climate responsive architecture. Besides, the architects or engineers from Sorane and Greentech Knowledge Solutions have a longstanding experience with sustainable buildings, which enables them to address many issues pertaining to sustainable building design, including ecological, near-zero and plus-energy buildings.

The *Integrated Design Charrettes* are therefore designed to establish a system whereby energy efficiency is considered as a primary goal among all the building functions that are pursued. The belief is that by adopting such methods in project design, the building project stakeholders will get accustomed to considering climate responsive and energy efficient solutions to respond to the needs of their future projects. The objective is to transfer a process as a working method rather than a solution in particular. The assumption is that as long as the right questions are raised and submitted to the right people at the right moment, which is what the Charrette allows for, adapted solutions will necessarily follow.

The *Integrated Design Charrettes* are geared to follow the standard building design phasing, which is a common reference to all key players of the building sector in India. The workshops will take place during the Concept Design (Phase 1) and on-going technical support will be provided until the Schematic Design (Phase 2) and thereafter. Following the schematic design, the building design is submitted to municipal authorization, and the Design Development takes place. At this stage, specifications are made and tender documents are prepared. The follow-on technical support will include two meetings to match the project timelines, one before finalization of the schematic design to provide further inputs where needed, and one after the final design, to validate the latter. The objective of the last session is also to evaluate the savings compared to the original project and to get feedback for further *Charrette* implementation. The *Integrated Design Charrette* support was geared to match Indian building project timelines to create a longstanding

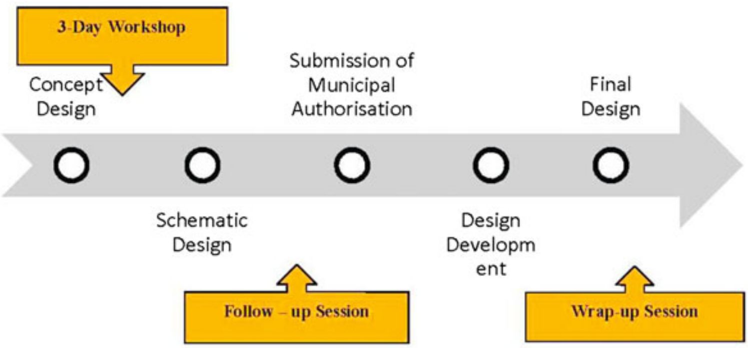

Fig. 16.7 Flowchart of the *Integrated Design Charrettes* phasing

mechanism, which can be easily adopted by Indian building professionals. Figure 16.7 illustrates how the *Integrated Design Charrettes* are designed to match key building design phases as they normally occur in India.

16.6 Conclusion

Integrated Design Charrettes appear to be an adapted mechanism to bring about change in building practices in India at a time when the Indian building sector is undergoing unprecedented growth, while the challenges for energy demand management are more important than ever.

The Building Energy Efficiency Programme (BEEP) is funded by the Swiss Agency for Development and Cooperation (SDC) and is consistent with the Energy Conservation Programme of the Indian Bureau of Energy Efficiency (BEE). Through its main component on *Integrated Design Charrettes,* BEEP aims at building the capacity of Indian building sector practitioners and raising their awareness on energy efficiency in buildings.

Lessons learned from the first *Integrated Design Charrettes* indicate that developers are keen to adopt the *Integrated Design Charrette* approach in their normal practice, as they appear to value the interdisciplinary methodology, the dynamic energy simulation skills and the practical expertise on energy efficient solutions provided by senior architects and engineers during the early design phase.

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Chapter 17
Effect of Participation in ICT-Based Market Information Services on Transaction Costs and Household Income Among Smallholder Farmers in Malawi

Samson P. Katengeza, Julius J. Okello, Edouard R. Mensah and Noel Jambo

Abstract There have been efforts in recent years to promote adoption of ICT-based market information services (MIS) to enhance smallholder farmers' access to agricultural markets. Application of such services improves information flow among users which enables economic agents to perform economic activities faster. In turn, farmers' welfare increases through reduced transaction costs which translate into improved agricultural income. In Malawi, although there have been rigorous efforts by the government and development partners to enhance application of ICT-based services, there are no known studies that have examined the impact on smallholders. This paper therefore examines the effect of participation in ICT-based MIS on transaction costs and smallholder farmers' agricultural income using propensity score matching technique. The paper finds that participation in ICT-based MIS reduces transaction costs facing smallholder farmers. There is also strong evidence that provision of ICT-based market information results into increased agricultural incomes. The findings imply that development strategy that embodies ICT-based MIS presents the farmer with means of resolving market failure that arises from high transaction costs. In particular, ICT-based MIS strengthen farmer linkage to agricultural markets. It therefore has the potential to help smallholder farmers escape the low-equilibrium poverty trap.

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17.1 Introduction

Adoption of ICT-based market information services (MIS) has increased in recent years in most developing countries including Malawi that are aiming at enhancing smallholder farmers' access to agricultural markets (Katengeza et al. 2011a). Agricultural markets play an important and inevitable role in sustainable poverty reduction and attainment of household food security in most of these countries especially in the Sub-Saharan Africa (SSA) region. Markets contribute to and are shaped by the wider systems of which they are a part. Systems that are more pro-poor in their final outcomes have understood, captured and utilized the essence of markets. Marketing could be a catalyst for change or a powerful way to preserve the status quo such that, the best marketer often gets the change he/she advocates.

Markets provide an important mechanism for efficient coordinated economic exchange such that promotion of more efficient and extensive markets and favorable access of the poor to markets is an important element in promoting their access to exchange mechanisms and hence enhance their livelihood (Dorward and Kydd 2005). Thus, application of ICT-based MIS in agricultural marketing provides such better access to markets through enhanced information flow among users. This then enables economic agents to perform economic activities faster by improving access to timely and accurate information. Such information promotes competition and improves market performance (Katengeza et al. 2011a) realize increased returns. In turn, farmers involved are able to enhance their welfare through reduced transaction costs which translates into improved agricultural income.

ICT-interventions attract attention because they are more effective in communicating knowledge to rural farmers; are more cost-effective and they facilitate access to markets. Consequently, farmers are able to boost their welfare through reduced transaction costs, increased output and reduced input price of agricultural commodities and eventually realize increased returns (Katengeza et al. 2011b). That is, farmers with more access to markets receive high output price, pay low input price, receive higher incomes and realize high gross margins than those with poor access to agricultural markets. In Malawi, the government in an attempt to loosen its grip on agricultural markets and expose farmers to the exigency of market forces embraced ICT-based applications in 2004 with the commencement of Malawi Agricultural Commodity Exchange (MACE).

However, to the best of our knowledge there are no known studies in Malawi that have examined the effect of electronic-based MIS interventions on smallholder farmers. The main objective of this study is therefore to examine the effect of participation in ICT-based MIS on transaction costs and smallholder farmers' agricultural income. In other words the study examines the effect of participation in ICT-based MIS on the level of crop income and the effect of ICT-based market interventions on transaction costs. Thus, to what extent has the electronic-based MIS reduced transaction costs among smallholder farmers in Malawi. The study uses the case of MACE Company as an electronic-based MIS intervention. The rest of this paper is organized as follows: Sect. 17.2 presents the conceptual framework and a description of empirical models used in this study. Section 17.3 gives the results and discussion while Sect. 17.4 presents conclusions and policy implications.

17.2 Conceptual Framework and Empirical Models

17.2.1 Conceptual Framework

Limited or poor access to the markets by smallholder farmers is a problem at both micro and meso–levels. At both levels, high transaction costs are the major cause of poor functioning of the markets. High transaction costs make input and output markets to fail at micro-level and impedes efficient functioning of the markets at meso-level by retarding the flow of price information between local/village and regional markets. This study therefore centers on the theory of Transaction Cost Economics (TCE), which is part of the New Institutional Economics (NIE) (Hubbard 1997; Clague 1997; Poulton et al. 1998). Transaction costs as identified and defined by Coase (1937) are costs associated with information, negotiation, monitoring, coordination, and enforcement of contracts. Thus, Poulton et al. (2006); Fafchamps (2004); Fafchamps and Gabre-Madhin (2006) and Okello et al. (2010) summed up transaction costs in the input and output markets of developing countries as search costs, negotiation costs, monitoring costs, enforcement costs, and mal–adaption (i.e., re-negotiation or contract adjustment) costs.

Transaction costs play an important part in the functioning of agricultural markets. On the other hand, the Performance of agricultural markets is seen as crucial in reducing poverty and attaining food security in most developing countries including Malawi. Food security can however, also be attained when markets function efficiently and therefore facilitate trade between different regions. Trade between different regions facilitates movement of food from food-surplus areas into food-deficit areas. Most governments have therefore been trying to loosen their grip with the aim of exposing their farmers to more efficient markets. Among several policies and interventions employed were the market liberalization policies and the recent ICT-based MIS.

The ICT services are theoretically believed to resolve the constraints smallholder farmers face in accessing better and efficient agricultural markets by reducing the transaction costs both farmers and traders face in facilitating trade transactions. First, traders can be more aware of the availability of the commodities, prices and volumes. This can reduce the cost of transport traders incur in searching for the commodities. At the same time, time spent in negotiating for a deal can relatively be reduced. While it could take a farmer or trader to travel from point A to point B to negotiate a deal, a phone call will do and within a shorter time a deal is sealed. However, the cost of phone call and other expenditure on other ICT tools can relatively increase. Nonetheless, the net income realized from a transaction is expected to increase.

17.2.2 Empirical Model

The effect of participation in ICT-based projects on transaction costs and household agricultural income is examined using Propensity Score Matching Technique. Positive impact of participation is expected to yield reduced transaction costs and increased household crop income. Transaction costs were measured as total costs incurred on travelling and telephone calls as well as time spent by farmers searching for both input and output markets. It is hypothesized that farmers who participate in ICT-based project would make more savings on transactions costs. Cost savings here refers to opportunity cost of time saved plus travel costs saved as a result of participating in the ICT-based projects. It is postulated that farmers that participate in the ICT-based projects would access market information provided by projects and hence would rarely travel to the markets as they would have otherwise done. Household agricultural income was measured as total crop sales for the year 2009.

Propensity score matching consists of matching treatment with comparison units (i.e., ICT-based project participants with non- participants) that are similar in terms of their observable characteristics and then computing the difference in outcome variables between the matches. These differences are then averaged to obtain the Average Effect of Treatment on Treated (ATT). Let Y_{i1} = outcome after treatment (i.e., participation in an ICT-based project), and Y_{i0} = outcome without treatment. Then the causal effect on i is given by Eq. 17.1:

$$Y_i = Y_{i1} - Y_{i0} \tag{17.1}$$

The estimated (or average) causal effect is thus given by Eq. 17.2:

$$E(Y_i) = E(Y_{i1} - Y_{i0}) = E(Y_{i1}) - E(Y_{i0}) \tag{17.2}$$

When using cross-section data, for impact evaluation, it is impossible to observe individual treatment effect since we do not know the outcomes for untreated observations when it is under treatment (Y_{i1}) and for treated when it is not under treatment (Y_{i0}). Propensity score matching therefore takes a treated individual and matches with a control of similar pre-participation characteristics. Any difference in the outcome (transaction cost and crop income) will then be attributed to the treatment (i.e. participation in ICT-based projects).

Propensity score is the probability of receiving a treatment given pre-treatment characteristics. Mathematically, the probability that an individual is treated, given the observable variables, can be expressed as in Eq. 17.3:

$$\mathrm{Prob}(x) = \mathrm{Prob}[P = 1|X = x] \tag{17.3}$$

where P = 1 is the observable treatment (participation in ICT-based projects) and 0 otherwise; X is a vector of pre-participation characteristics including farmer-specific, farm-specific, asset endowment and regional/location variables. Preceding the propensity score matching (PSM) technique is a logit or probit model that estimates the participation equation. In this study, the implicit functional form of estimated participation equation is given by Eq. 17.4:

$$\begin{aligned}&\textit{Participation} = \textit{project participation}\ (\textit{age}, \textit{gender}, \textit{occupation}, \textit{distance to}\\&\textit{the market}, \textit{number of enterprises}, \textit{household size}, \textit{income}, \textit{value of assets},\\&\textit{education}, \textit{farming experience}, \textit{non} - \textit{farm experience group membership},\\&\textit{regional dummies}) + e\end{aligned} \tag{17.4}$$

where e is the random error term.

The estimated scores are then used for matching the participants (treatment) and non–participants (control). Four techniques are used in the matching process namely, Nearest Neighbor Matching (NNM), Radius Matching (RM), Kernel Based Matching (KBM) and Mahalanobis Metric Matching (MMM) techniques. A description of these techniques is outlined by some of the previous studies like Smith and Todd (2005). All these matching algorithms compute the difference between the matched treatment and control which is then averaged to obtain the ATT and it measures the impact of an intervention (participation in ICT-based projects).

17.2.3 Study Area, Sampling Procedure and Data Collection

The study was conducted in all three regions of Malawi in the following districts: Mwanza in southern region, Dedza in central region and Mzimba in northern region. The districts were selected based on active participation of farmers in ICT-based MIS. The study targeted farmers from both ICT and non-ICT based project areas. An ICT project area was defined as an area where an ICT-based market intervention (in this case MACE) whose aim is to facilitate smallholder farmer linkage to markets through the use of new generation ICT tools especially the mobile phone was available.

A combination of purposive, stratified and random sampling techniques was used. First, the respondents were purposively and stratified based on participation to ICT-based agricultural projects whereby in each district, an area with MACE project was identified. Second, for each area, a list of all farmers was drawn from MACE registered members with the help of MACE staff. Similarly, a list of farmers was drawn with the help of village headmen from an area without MACE project. Third, respondents were sampled from the two lists using a random sampling technique. The final sample was 410 with 260 MACE participants and

150 from non-ICT project area. Data collection was through personal interviews using a pre-tested questionnaire. The data collected included farmers' characteristics, farm characteristics, household capital endowments and use of ICT services in marketing activities. The survey was done between March and April 2010.

17.3 Results and Discussion

The results of logit regression model fitted as a first step of the propensity score matching estimation of the impact of participation in ICT-based MIS project are presented in Table 17.1. Results show that gender, distance to output market, distance to electricity source, literacy, social capital (proxied by membership to a farmer organization), endowment with physical assets and education are significant in the model. Other things constant, endowment with physical assets, literacy, distance to the output market, and district in which the farmer is located increase the probability of participation in ICT-based projects. On the other hand, distance to electricity source from the farmer reduced the likelihood of participation in ICT-based projects, other things constant. As expected, male farmers have a lower likelihood of participating in the ICT-based MIS project than their female counterparts, ceteris paribus.

The effect of participation in ICT project on agricultural income and transaction costs was then estimated based on propensity scores generated from the logit model with NNM (with replacements), RM and KBM techniques. The distribution

Table 17.1 Propensity scores for participation in MACE project: Logit regression results

Variable Definition	Logistic regression	
Dependent variable: Participation in ICT-based project	Coefficient	p value
Farmer-specific variables		
Gender of the household head (dummy)	−0.776	0.036
Literacy of household head (dummy)	0.091	0.829
Farm-specific characteristics		
Distance to output market (km)	0.132	0.000
Distance to electricity source (km)	−0.031	0.014
Number of crops	0.008	0.764
Asset endowment characteristics		
Natural log of assets prior to project	0.420	0.000
Natural log of livestock value	−0.002	0.614
Group membership (dummy)	2.772	0.000
Regional characteristics		
Central (dummy)	0.988	0.061
North (dummy)	1.359	0.014
Constant	−4.507	0.000
Number of obs = 410 Prob > chi2 = 0.000		
Log likelihood = −133.97 Pseudo R2 = 0.576		

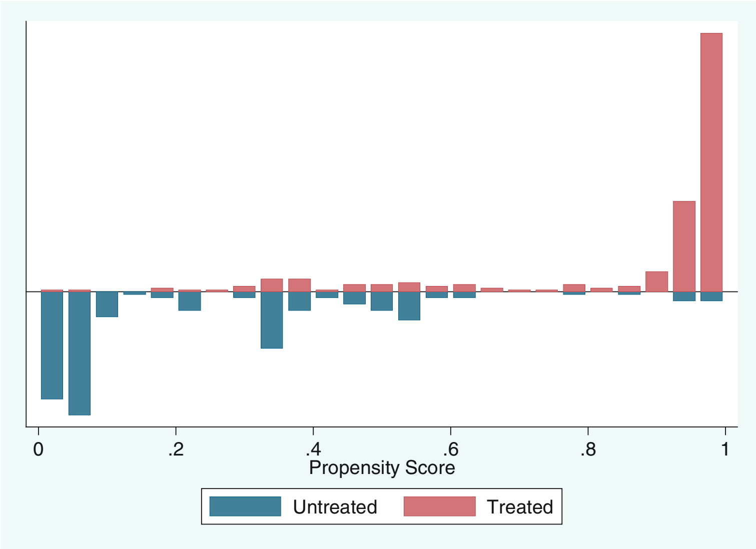

Fig. 17.1 Propensity score distribution & common support for propensity score estimation

of the propensity scores calculated following the logit model is presented in Fig. 17.1 which also gives the region of common support.

All individuals are in the region of support indicating that all treated individuals have corresponding untreated individuals. Treated indicates the individuals in the ICT project participation group whereas untreated indicates individuals in the non-participation group (also referred to as controls). The graph in Fig. 17.1 shows that matching was done within the region of common support. It also shows skewed distribution of the propensity scores between the groups of ICT project participants and non-participants and hence the need to impose the common support condition to avoid bad matches.

Table 17.2 presents the ATT for the two outcome variables estimated using the NNM, KBM and RM matching algorithms. The results from all matching approaches indicate that participation in ICT-based projects has a positive and significant effect on both reduced transaction costs and small farm household agricultural income. Specifically, the results suggest that the reduction in transaction costs is higher among those who participated in MACE project than for the non-participants. This reduction in transaction costs coupled with increased knowledge of available better paying markets as per market information provided by the ICT-based MACE intervention translates into increased incomes. Results show that the ATT for the transaction costs is significant at 5 % with all the three matching techniques. Participation in ICT-based projects reduces transaction costs by 622 Malawi Kwacha (MK), MK611 and MK606 with NNM, KBM and RM techniques, respectively with agricultural incomes increasing by MK36,974, MK39,374 and MK40,212, respectively. This suggests that participants in ICT-

Table 17.2 Effect of participation in ICT projects

Matching Algorithm	Outcome Variable	ATT	t-values
Nearest Neighbor Matching (NNM)	Reduced Transaction Costs	622.71	2.81
	Household crop income	36,974.12	1.99
Kernel Based Matching (KBM)	Reduced Transaction Costs	611.18	2.78
	Household crop income	39,373.85	2.30
Radius Matching (RM)	Reduced Transaction Costs	606.16	2.76
	Household crop income	40,211.81	2.40

Number treated = 261; Control = 149

based projects faced lower operational costs (transaction costs) since the project provided market information and hence savings on travel and time costs they would have otherwise faced by travelling to and from the market for the same information.

The findings imply that participation in ICT-based MIS interventions such as MACE reduces transaction costs facing smallholder farmers. The results also present strong evidence that provision of ICT-based market information results into increased agricultural incomes. The findings further suggest that development strategy that embodies ICT-based MIS presents the farmer with means of resolving market failure that arises from high transaction costs. In particular, ICT-based MIS strengthen farmer linkage to agricultural input and output markets. It therefore has the potential to help smallholder farmers escape the low-equilibrium poverty trap that is usually characterized by limited use of agricultural inputs, low participation in , low incomes and subsequently low input use, again.

However, government's continued involvement with control policies in agricultural marketing especially for staples such as maize emerge as one serious threat to the success of ICT-based market interventions in Malawi. Although such policies such as export ban or price controls may be good for national food security they have a negative effect on international trade. The price controls affect local traders because they operate at a loss and may fail to service remote areas. Other challenges include poor supporting infrastructures such as roads; poor mobile phone network coverage; lack or limited ICT tools such as mobile phones, internet/web-based applications, interactive video and CD−ROM programs and high ICT service provision tariffs.

17.3.1 Test for Hidden Bias and Sensitivity Analysis

After carrying out propensity score analysis, the study conducted a test for as well as in order to compare the situation before and after matching and check if there were any remaining differences that were likely to affect the outcome variables. This test can be achieved by three methods proposed in the literature namely; comparison of median absolute bias before and after matching, comparison of

Table 17.3 Indicators of covariate balancing before and after matching

Tests	Reduced Transaction Costs		Household crop income	
	Before Matching	After Matching	Before Matching	After Matching
Median bias	24.86	9.23	24.66	9.19
% bias reduction		98.3		90
Pseudo R2	0.36	0.124	0.33	0.062
LR Chi square	192.75	89.49	174.42	45.14
P-value of LR	0	0.369	0	0.369
Critical level of Hidden bias (Γ)		1.85–1.90		1.80–1.85

value of R-square before and after matching, and comparison of joint significance of covariates before and after matching. The results of the test for hidden bias are presented in Table 17.3 and reports only for NNM algorithm. The estimates show that the standardized difference in bias before matching was 25 %, while the remaining standardized difference after matching was 9 % for both outcome variables of transaction costs and agricultural income. The reductions in the median absolute bias were both greater than 20 % (with TC reporting 98–90 % for agricultural income) and hence are considered 'large'. The large reduction in bias improves matching quality (Rosenbaum and Rubin 1983).

Results for the pseudo-R^2 before and after matching also presented in Table 17.3 show that the pseudo-R^2 after matching was lower than before matching. For example pseudo-R^2 decreased from 0.36–0.12 for transaction cost outcome while for crop income there is a reduction from 0.33–0.06. This implies that after matching there were no systematic differences in the distribution of covariates between both participants and non-participants of ICT-based projects. The third measure of covariate balancing is given by the p-values of the likelihood ratio tests before and after matching. The results as presented in Table 17.3 indicate that the hypothesis of joint significance of the regressors is not rejected before matching but rejected after matching. This suggests that there were no systematic differences in the distribution of covariates between participants and non-participants of ICT-based projects.

Results of the sensitivity analysis on hidden bias (i.e., critical level of hidden bias), which show the critical levels of gamma, Γ, at which the causal inference of significant impact of participation in ICT-based projects may be questioned are also presented Table 17.3. Gamma measures difference in the response variable between treatment and control cases. For example, the value of 1.80–1.90 on transaction costs implies that if the individuals that had the same characteristics were to differ in their odds of participation in ICT-based projects by a factor of 85–90 %, the significance of the impact of participation in ICT-based project on transaction costs would be questionable. The lowest critical value of sensitivity analysis is 1.80–1.85. These results suggest that even large amounts of unobserved heterogeneity would not alter the inference about the estimated effects of participation in ICT-based projects on transaction costs.

17.4 Conclusions and Policy Implications

The results of this study have shown that participation in ICT-based projects has a positive and substantial effect on reduced transaction costs. It has also been shown that participation in ICT-based projects has a significant impact on the level of household income. Specifically, the results suggest that reduction in the amount of transaction costs is higher among participants of ICT-based MIS projects than non-participants, something which has been translated into increased income. The lower transaction costs faced by participants imply that the participants were able to save time and travel costs as a result of using market information provided by MACE. The test for hidden bias and sensitivity analyses reveals that even large amounts of unobserved heterogeneity would not alter the inference about the estimated effects of participation in ICT-based projects on the level of transaction costs.

The findings of the study imply that development strategy that embodies ICT-based MIS presents the farmers with a means of resolving the market failure that arises from high transaction costs. In particular, the findings imply that ICT-based MIS projects strengthen farmer linkage to agricultural input and output markets. It therefore has the potential to help smallholder farmers escape the low-equilibrium poverty trap that is usually characterized by limited use of agricultural inputs, low participation in agricultural markets, low incomes and subsequently low input use, again. Focus should therefore be made on promoting active participation and usage of ICT-based MIS.

In particular, special consideration should be on group membership to enhance participation and use of ICT-based MIS even in areas the interventions are not operating. The interventions should consider means of making the services affordable to maximize accessibility by rural farmers so that it does not favor only the well to do households. Male participation is another area the interventions should look into. In most areas in Malawi, males have more access to productive assets and their active participation will enhance the positive impact of the project. Again, evidence has shown that those farmers in more remote areas participate more in MACE activities. Thus, MACE and other ICT-MIS providers should target more remote farmers with the services. MACE is the main source of information in such areas thus enabling these rural farmers to make informed decisions. Finally, the government of Malawi should work on minimizing controls in agricultural marketing, ICT service providers should enhance network coverage and reduce service costs and support infrastructures such as roads and ICT tools should be improved.

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Chapter 18
Participatory Processes in Urban Planning Projects in China: The Example of Caoyang Village, Shanghai

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Abstract In order to provide the first elements of a participatory process initiated and led by Chinese authorities, this paper will look at the citizen's involvement in an urban planning project in China and discuss possible avenues to sustain the process in a specific local context over the long-term. Since the end of the 1980s, most community participation projects in China have been implemented in rural environments. This participatory process was carried out in Shanghai's historically and culturally symbolic Caoyang Workers' Village, without the external influence of international bodies. Even if some constraints have emerged in the participation of citizens during the pre-project phase, this participatory process seems to have fostered local governance to make significant breakthroughs. It was also the opportunity to reflect upon the minimum conditions to ensure the sustainability of this type of practice in Chinese urban planning projects by adopting the vision of an adapted participatory process.

18.1 Introduction

After a quarter of a century of practical application and abundant literature, participatory approaches are still prone to wide criticism, some of which appears particularly relevant when the focus is on the impact such approaches may have on a social context that is both complex and difficult to apprehend. Most advocates of

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participation, who recognize that the main conditions for their success are based on local social, institutional, political and cultural factors over which they feel they have little control, also share this view. Yet, it seems possible to take greater account of these criticisms by explicitly thinking of participation as a strategy in terms of an entire local social context rather than a method merely focused on conducting consultation workshops (Aquino 2009). Therefore, it comes as no surprise that participatory processes come in a variety of forms, "*it is not a simple, linear set of replicable rules but an approach constantly adapting to a complex combination of political, economic, institutional and cultural forces*" (Plummer and Taylor 2012). Participatory processes were introduced in China at the end of the 1980s, a particular period of modern Chinese history. This led authors (Enserink and Koppenjan 2007; Plummer and Taylor 2012) to argue that the common agenda for introducing these processes in China and in other countries was an intention to shift the development paradigm, to promote a people-centered approach that prioritized demand over supply mechanisms, was inclusive of poor communities, and created a role for them in their own development. In each context, the introduction of these processes primarily aimed to consider the people as participants rather than beneficiaries. "*The differences in China stemmed from a unique relationship between the people and the state, the specificities of a centralised system of government, and the burden of history in which collective action and mobilisation were characteristic, but in a vastly different form and context to the goals and aspirations of the participatory movement elsewhere*" (Plummer and Taylor 2012). There is little research dealing with implementation of these practices in non-democratic countries and in the case of China, in urban settings (Klimova 2010). This paper aims to provide the first elements of a participatory process initiated and led by Chinese authorities, without the external influence of international bodies, under a project in an urban environment, and not a rural one – as was the case in most community participation projects since the end of the 1980s. This process was conducted in Caoyang Workers' Village, a national symbol due to its location in Shanghai, but also due to its specific history, namely a prime example of China's links with the Union of Soviet Socialist Republics (USSR) and of the meritocratic system implemented by Mao Tse-Tung. It was one of the first times that the public consultation process was officially included by the local authorities in the city's five-year plan. Therefore, as a first step, it seems important to accurately define the terms of participatory process and local governance before reviewing the history of community participation's implementation in China and what form the analysis of participatory approaches may take in specific local contexts. Indeed, the example of the redevelopment project of Caoyang Workers' Village in Shanghai and its *Neighborhood 1*, discussed in Sect. 18.3, includes numerous specificities. Ultimately, although some constraints have emerged in the participation of citizens in this pre-project phase, this process seemed to have enabled local governance to make significant breakthroughs. It also provides an opportunity to reflect upon the minimum conditions to ensure the sustainability of this type of practice in Chinese urban planning projects by adopting the vision of an adapted participatory process.

18.2 Participatory Process in Urban Planning Projects: Approaches and the Case of China

18.2.1 Participatory Approaches in Urban Planning Projects

Community participation in urban development and planning projects has changed significantly over the last decades. Thus, in the aftermath of World War II in Europe, the issue of involving communities in planning projects was not raised, "*town planners tended to assume they know best what sorts of physical environments were unfit for people to live in. Accordingly, they did not even consult the inhabitants about how they would like to see their surroundings planned*" (Taylor 2005). This total lack of community participation, let alone community consultation, triggered protest from the people concerned, as exemplified in many cities of the United Kingdom in the 1960s. In these democratic States, the acknowledgment of the inherently political character of urban planning decisions led to a greater awareness of the authorities in charge of such issues about the need to involve communities, one way or another, in the decision-making process. However, there was first some equivocation between the view that the public should decide public policy and the view that planners themselves should prescribe what they thought right or appropriate. In other words, "*participation was primarily seen as involving more consultation with the public rather than the public actively participating in decision-making*" (Taylor 2005). The idea that participation should not only imply consultation but active participation was put forward by Sherry Arnstein in her famous paper "*A Ladder of Citizen Participation*" in which she conceptualizes, with the help of a "ladder", the various degrees of citizen participation (Table 18.1).

With her diagram on public participation, she focuses on what degree the public should be given a say in, and beyond that real power to decide their affairs (Taylor 2005). Here, participatory approaches refer to any arrangement by which players – stakeholders – of various types are gathered with a view to contributing to the decision-making process in a more or less direct and more or less formal manner. Thus, the concept of participation relates to the involvement in decision-making processes of individuals outside of the formal political and administrative circle and who, presumably, do not necessarily conform to its standards (Van den Hove 2001). Some authors also use the term "consultation" to designate these participatory processes. Yet, literally, to participate means "to take part in something", whereas to consult means "projecting something in common"[1]. As such,

[1] The term consultation is often used in politics to designate the process by which stakeholders confront each other and finally agree to act together, but it has also commonly acquired the meaning of consulting interested parties prior to any decision, which does not hold the same significance as when one makes the assumption that a decision will be made collectively (Van den Hove 2001).

Table 18.1 A Ladder of Citizen Participation[a]

	Citizen Control Delegated Power Partnership	Citizen Power
	Pacification Consultation Informing	Tokenism
	Therapy Manipulation	Nonparticipation

[a] Adapted from Arnstein 1969

participation is a wider concept, which encompasses that of consultation. As previously indicated, the issue here is to question these participatory processes in a specific local context.

18.2.2 *Participatory Process and its Impact in Terms of Governance*

In various countries, community participationin urban planning projects has increased "*with the underlying assumption that if citizens become actively involved as participants in their democracy, the governance that emerges from this process will be more democratic and more effective (…). Arguments for enhanced citizen participation often rest on the merits of the process and the belief that an engaged citizenry is better than a passive citizenry*" (Irvin and Stansbury 2004). Many authors (Arnstein 1969; Brody et al. 2003; Enserink and Koppenjan 2007) have therefore established a link between community participation and the integration of local governance in the principles of democratic governance. These principles include the right of individuals to be informed, consulted and to have the possibility of expressing their views regarding the governmental decisions that affect them. Other recent benefits of participatory processes include: citizen participation can generate trust, credibility and commitment regarding the implementation of projects and can be a factor of social capital building (Brody et al. 2003). Therefore, to develop the participation of local residents corresponds, at varying degrees, to an ethical principle reflected here in the introduction of the notion of local governance. But what does local governance really mean? According to Stocker (1998): 1) it brings into play a set of institutions and stakeholders that do not all belong to government circles; 2) borders and responsibilities are less clear in the field of social and economic action; 3) it reflects an interdependence between the powers of institutions associated with collective action; 4) it includes networks of autonomous players; 5) it is based on the assumption that it is possible to take action without relying on the power or the authority of the State. Unlike in Western countries where this issue has concurrently emerged with the notion of sustainable development (Bolay 2012) and, for example, the implementation of Agenda 21 in many cities (Thuillier et al. 2002), these principles of local governance cannot be applied in certain contexts. Namely, according to Stocker's definition, points 4 and 5 cannot be applied to certain Asian non-democratic countries where the Constitution only grants one party the right to govern. As a result, the existence of autonomous stakeholders or the hypotheses of actions stretching beyond the sphere of control of the State seems impossible. Thus, the primary goal for this paper is to question the emergence of participatory processes in development projects in China, first in rural areas then in urban entities.

18.2.3 Emergence of Participatory Processes in China

The many changes that took place after 1978 in China created a favorable context for the implementation of pilot participatory processes, in rural environments in particular. The 1987 Organic Law of the Villagers' Committees led to elections which, in spite of widespread abuse in their conduct, had a major impact in terms of local governance (Plummer and Taylor 2012), since the people could at last express their views on the decisions that were affecting their everyday lives. This paradigm shift allowed developing numerous community projects in the early 1990s mainly under the initiative of bilateral donors and international bodies[2]. At the national level, the authorities were focusing on their primary goal of reducing poverty through economic growth. Although national entities were officially fostering this type of initiative financed by international funds, the marginal nature of these projects and their divergence with major national policies was putting the local authorities in a contradictory position, since they both had to fulfill their traditional duties as local relays of national policies – a typical top-down policy approach – and to promote the bottom-up approach inherent to participatory processes introduced in international projects (Plummer and Taylor 2012). Projects including a participatory component have developed sector by sector, only at a micro-level, according to funds allocated by international donors and according to their concerns, primarily in the areas of rural development, the economy, and the environment and water and forestry resources (Enserink and Koppenjan 2007). However, in spite of criticism about the weak impact of these projects due to their limited scale, the resolve of international bodies allowed the creation of new

[2] For instance, the German Agency for Technical Cooperation (GTZ) supported the Centre for Integrated Agricultural Development (CIAD) in Beijing, which had started to introduce new concepts such as citizen participation and to embed them in their teaching and in their field studies (Plummer and Taylor 2012).

models of community development, which impact in terms of poverty reduction captured national concerns. Therefore, since the 2000s, the growing interest of the authorities for methodologies producing targeted results in terms of poverty reduction materialized through the adoption at the national level of a strategy to reduce endemic poverty in villages with one major innovation, the introduction of community participation among other. Although community participation in development projects has gained ground gradually in rural areas over the last decade, these processes have only recently started to be experimented in urban settings and only when it is related to environmental issues (Enserink and Koppenjan 2007). Furthermore, this has often happened in very particular urban entities due to their influence and visibility at the national – or even international – level, as is the case of Shanghai and Caoyang Workers' Village.

18.3 Redevelopment Project of Caoyang Workers' Village in Shanghai and Citizen Participation

18.3.1 Chinese Urbanization and Governance System, the Case of Shanghai

The exponential urban growth of China over the last decades continues at a staggering pace: it has increased from less than 18 % in 1978 to almost 40 % in 2010 (Xun et al. 2010) and to 70 % by 2035 (UNFPA 2007). While the rate of urbanization in China still remains lower than the world average (50 % since 2009), the country's pace of urbanization is nonetheless unprecedented (Xun et al. 2010). Two main urban development trends can be drawn from this urbanization process. One is the transformation of rural areas into urban areas, primarily through the development of new towns coupled with diminishing arable land and farmland areas due to the significant associated land pressure. The second main trend is the redevelopment of old urban areas, a growing phenomenon particularly in the most developed cities. This is a direct effect of the adoption by China of "*an incomplete urbanization approach, arguably to economize on the costs of urbanization in the process of rapid industrialization. This is typical of many countries pursuing a Soviet-type economic growth strategy, the outcome of this phenomenon called 'under-urbanization' (…). This incomplete urbanization is achieved mainly by allowing temporary migration (of a 'floating population') to cities but denying the migrants access to urban welfare and many other benefits*" (Wing Chan 2010). The case study presented in this paper illustrates precisely this trend in Shanghai. Indeed, following decades of social and economic development, Shanghai, with its population of more than 22 million, has become China's most developed city. At the same time, Shanghai epitomizes a city experiencing a revival, shaped by the laws of the market and of numerous private property developers. Falling directly within the jurisdiction of the central government (along with the cities of Beijing, Tianjin and Chongqing), Shanghai has a two-level state, the municipal and district governments, and a three-level administration, which comprises a municipality, districts and sub-districts (Ma 2011). The administrations of sub-districts will be hereafter referred to as grassroots governments. The willingness of Shanghai's grassroots governments to involve citizens in the redevelopment project of Caoyang Workers' Village in Shanghai and to include it in the 12th five-year plan of the municipality[3] (town-planning and five-year economic development schemes, for which priorities are set out by the central government) has nevertheless attracted widespread attention throughout the country.

18.3.2 Caoyang Workers' Village and its Neighborhood 1

The new government established in 1949 took immediate measures by launching a large-scale campaign to eradicate impoverished neighborhoods and fight against insalubrity in large cities. In parallel, the government built new public housing in these areas to cope with the accommodation shortage. Generally made of multi-story buildings laid out in parallel rows, these new building projects are often called "new villages" or "workers' villages". The planning and design of these buildings and residential communities was strongly influenced by the Soviet model, according to which a change in people's living conditions inevitably led to a change in social behavior. In China, these housing types aimed to gather people in communal neighborhoods by encouraging a collective and socialist lifestyle, a remarkable improvement compared with prior living conditions (Ma 2011). Caoyang's *Neighborhood 1*, located in the center of Caoyang Village, was the first workers' housing project built in early 1951 by the municipality of Shanghai, for workers of the West Shanghai industrial area (1002 apartments allocated to the workers of 217 state factories). At this time, inhabitants were either "advanced producers" or "model workers" rigorously handpicked from textile and hardware industries. The layout of Caoyang Village adopted the new spatial model of the "great Soviet residential area" in the 1950s, with a strict layout of rows made of three to four housing units, each unit including two floors of three apartments (one-room and one-and-a-half room apartments). The three households living on one floor shared a communal kitchen. The new village's inhabitants were fairly homogenous in terms of age, family origin, profession, economic condition and

[3] *"Persist in people-orientation and reconstruction according to law. The resolution of the masses' housing difficulties and improvement in their housing conditions shall be taken as an important goal of old town reconstruction. In respect of the determination of land plots to be reconstructed and the formulation of compensation and resettlement schemes, it is imperative to fully respect the people's will in strict compliance with the provisions of relevant laws and regulations, so that the masses' legitimate rights and interests might be maintained, and their real benefit be guaranteed"* (Shanghai Municipal Government 2010).

political convictions, being both neighbors and colleagues. As for occupancy status, *Neighborhood 1* is characterized by the work unit system: the State owns the housing while the right to use the property befalls on the work unit, which allocates the housing to their employees and workers at virtually no cost. The housing's repair and management are settled collectively by the property management office to which inhabitants pay a modest monthly rent (Ma 2011; Matthey 2011). To maintain these rental units at affordable prices and to alleviate the share of housing-related expenditures in the budget of urban households, the government had implemented a low rent policy, which often only amounted to 1 % of household spending (Kim 1990). But these low prices barely covered maintenance costs. Public spending on housing soon became a particularly costly investment with negative returns: as public housing construction increased, the subsidies needed for their upkeep shot up.

18.3.3 The Rehabilitation Project of Caoyang's Neighborhood 1 and the Introduction of Participatory Process

Over the years, the housing units started to substantially deteriorate (derelict buildings, obsolete and non-compliant water and sanitation networks, illegal electrical connections, etc.). Moreover, the stable structure between work units, inhabitants and housing inherent to workers villages was profoundly affected in the 1990s during a series of institutional reforms, in particular those related to state companies and the commoditization of housing units. The situation became even more complex in *Neighborhood 1*, given the communal spaces such as the kitchen and toilets shared among several families, which made it difficult to divide housing into private apartments. Therefore, the housing units of *Neighborhood 1* could not really be placed on the market and their right of use remains unclear under the current policy. Moreover, although the breakdown of the work unit system and the reform of the housing system provided opportunities in terms of the residential mobility offer, the large quantity of workers-farmers who have flocked to Shanghai since 1990 also generate a strong demand for housing. Due to these various tensions, some parts of Caoyang Village were simply demolished and then rebuilt, with relocation of inhabitants there or in peripheral neighborhoods. Two neighborhoods attracted particular attention from the authorities: *Neighborhood 1* and *Neighborhood 7*. Particular focus in this paper is placed on the first one due to its cultural and historical significance, being the birthplace of national leading figures such as Jiang Zemin, the People Republic of China PRC's former president. This substantial historical heritage has led the authorities to grant the neighborhood a privileged status: reconstruction solely under political mandate is strictly forbidden in this Village. In line with their resolve to turn this project into an example in terms of rehabilitation, the authorities have also encouraged citizens to participate in accordance with the municipal government's new directives set out in 2010[4]. The Chinese authorities' interest for the introduction of participatory processes in urban development projects is largely the consequence of the proliferation of popular protests and response in the face of the forced evictions and relocation procedures that have marked urban policies in China since the end of the 1970s. These protests have gathered more importance over the last decade (Xiaolong 2010) and have gained resonance as Chinese society is opening up to the outside world, in particular when it is linked to cultural or architectural heritage (Leroux et al. 2011). Strongly guided by the Shanghai municipality, the community participation was organized by the grassroots government and Shanghai Jiao Tong University (SJTU) on the Caoyang's project and despite the rather weak impact of this participative process at this stage, there have been real breakthroughs in terms of local governance and courses of action for greater efficiency.

18.4 The Citizen Participation: Some Breakthroughs in Terms of Local Governance and Courses of Action for Greater Efficiency

18.4.1 The Survey and its Impact on Local Governance

In 2010, on an area of 10.8 ha, *Neighborhood 1* had 1,918 households with 5,670 inhabitants and 4,500 people registered in the *hukou*[5] system. The rehabilitation project was launched the same year by the "Caoyang's street office" (the grassroots government, namely Caoyang Village's administration and its catchment area) with the involvement of the inhabitants in the redevelopment project. On the one hand, this participation took place through consultation with resident committees, and on the other hand, through a questionnaire-based survey with "workers' villagers". More than 200 households responded to the various basic questions regarding the origins of the population and on their perception on the urgency of the project. A total of 148 questionnaires were completed and used by SJTU to prepare the pre-project. One of the first outcomes of the survey concerned

[4] "Encourage all parties involved to participate. In the process of old town reconstruction and house demolition and relocation administrative department shall establish a system of the third-party participation, invite representatives of the people's congress, members of the CPPCC, professional lawyers, personnel of public trust, representatives of residents, the department of civil affairs, petition letters and calls, discipline supervision and investigation, and auditing, and sub-district offices to jointly participate in and supervise the work of house demolition and relocation for old town reconstruction, and stop resolutely, investigate and handle the acts which damage the masses' legitimate rights and interests" (Shanghai Municipal Government 2010).

[5] The residential mobility of Chinese city-dwellers is characterized by the implementation of a *hukou* scheme (household registration), which requires that all urban residents shall live exclusively in the housing recorded in the *hukou* register (Wing Chan 2010; Zhang 2010).

the demographic structure of this Worker's Village. Migrants represent 25 % of the inhabitants, and the people registered in *hukou* amount to 75 % (with a large majority of them being retired). More than 50 % earn less than 2,000 RMB (*renminbi*, official currency of China) per month and only 13 % more than 4,000 RMB per month[6]. The second main output of the survey was to emphasize the urgency of the project. Although the neighborhoods' immediate environment is relatively attractive (green spaces, collective amenities, proximity with the center of Shanghai), the condition of kitchen structures and housing is becoming progressively worse. The gap between the city's social development leaks, lack of indoors daylight, illegal electricity connections and unauthorized constructions contribute to the urgent need to rehabilitate the neighborhood. Therefore, of the 200 families questioned for the survey, 98 % of respondents expressed their support for the demolition and reconstruction of apartments and 97 % requested the immediate improvement of the living standards in the neighborhood. One of the breakthroughs related to this survey was to identify the residents' priorities and their commitment to redevelopment. It was also an opportunity for the authorities to realize that a majority of long-term residents from *Neighborhood 1* were truly aware of its particular status whereas newcomers had almost no idea of the historical value of their place of residence. On this basis, SJTU and Caoyang Street Office presented a pre-project to the Shanghai municipality.

18.4.2 Lessons Learned from the Failure of the Pre-project

The main inspiration of this pre-project, developed in 2010, was the example of Xujahui, a Shanghainese neighborhood which was an industrial area before being transformed at the beginning of the last decade into a commercial area. After the identification of potential commercial places, the main proposal of the pre-project was the enlargement of the main street of Caoyang, Lanxi Lu road, in order to modernize the commercial structure and to couple it with the rehabilitation of the closest neighborhood to improve their market's value. Thus, in the case of *Neighborhood 7*, priorities were set on factors of mobility and accessibility to transportation with a partial demolition of the residential buildings to enlarge Lanxi Lu road whereas in the case of *Neighborhood 1*, its specific historical and cultural dimensions were an integral part of the pre-project. Indeed, it is on this basis that a selective protection plan has been devised for *Neighborhood 1*: one third to be preserved, two-thirds planned for demolition. Already at this stage, the proposal raised three major questions: the type of conservation model to be adopted for one third of the buildings (like a museum model, known as

[6] Knowing that the average minimum wage in Shanghai is 1,080 RMB per month, approximately 135 € (Matthey 2011).

"*Xintiandi*"[7]); the type of model imposed on the other two-thirds from an architectural and financial point of view and from the perspectives of the inhabitants. Two years after the survey and the presentation of the pre-project by SJTU and Caoyang Street Office, the Shanghai Municipality Government decided in 2012 not to take it up for the moment, for different reasons. The main one is the actual difficulty to mix usual urban renovation logic, more based on commercial potentialities, and neighborhood's rehabilitation which has a specific demographic structure and a real heritage value. In China, heritage is more and more seen as a potential financial manna after being formerly accorded a kind of victim status, especially in underdeveloped areas. But the look for short-term profit has too often led to the development of commercial operations excluding, for example, any kind of mixity, thus damaging the authenticity of the sites on which they are built (Leroux et al. 2011). Another reason is the economic and social contexts which have also a tangible impact on this type of urban planning project. The International exhibition of 2010 increased the costs of relocation more rapidly than the prices on the real estate market: a redevelopment project such as the one proposed is therefore too expensive for the real-estate companies (Liu 2008). Nevertheless, through this process, the grassroots government has shown a certain will to cooperate with inhabitants and some of the issues highlighted by a number of stakeholders, such as resident committees and research institutions, seem to have been factored in gradually. It is indeed during the drafting of this pre-project that rehabilitation priorities were set and that the decision was taken to focus on *Neighborhoods 1* and *7*, due to their characteristics and their urgent need for renovation. But we could question the schedule of this participative process and we can assume that if the inhabitants would have participated to the whole process, some concerted findings could have emerged, despite the constraints linked to the actual Shanghainese context.

18.4.3 Avenues of Action to Improve the Participatory Process in the Rehabilitation Project of Neighborhood 1

The authors saw that participation is a wider concept, which encompasses that of consultation. From this case study, it seems that it would have been interesting to measure the level of participation according to Western's standards, as these participatory approaches were relatively new in urban areas. Based on Arnstein's ladder of participation, the participatory process described in Sect. 18.2.1 would

[7] From the name of a Shanghainese area which was entirely renovated and transformed into a pedestrianized area with shops and restaurants: "*even though the project involved the demolition of the old neighborhood and the relocalization of all its inhabitants, it is now a genuine model of commercial development for numerous Chinese cities* " (Leroux et al. 2010).

Table 18.2 Ladder of Community participation in China (reprinted here with the kind permission of Taylor & Francis. *Data source* Plummer and Taylor 2012)

Ladder of participation in EU[a]	Ladder of community participation in China
Co-decision	Initiative / Self-management
Co-production	Decision making
Advise	Discussion
Consultation	Expression
Information	Attendance
	Notification

[a] Inspired by Arnstein 1969

have reached Level 3, consisting of the public being informed (i.e., the inhabitants were aware that a pre-project was underway). However, to fully attain a certain degree of tokenism, that is to say to make a perfunctory gesture toward the inclusion of members of minority groups, the inhabitants should be consulted throughout the whole process, beyond the mere delivery of information. In fact as noted by Aquino (2009), the point is to explicitly consider participation as a strategy towards an entire local social context. Yet, even if academics and development practitioners agree that public participation in China is different, it is difficult to make conclusions on how different the process is (Klimova 2010). According to Zhao (2010), the main contrast between participation in the West and in China is that in a Chinese context, participation is traditionally seen as a form of "mass participation", leading people to support both the government and the Party in the implementation and enforcement of State laws and party policies. This observation calls for an adaptation of Arnstein's ladder to the Chinese specific context since "*there is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcome of the process*" (Plummer and Taylor 2012). Similar to information in Arnstein's ladder, notification and attendance in Plummer and Taylor's ladder of community participation (Table 18.2) are the very first stages of participation; they are prerequisites for meaningful participation; the latter only starts when a community is given the opportunity to express their views.

It seems important to recall that the decision-making issue in a participatory context raises the question of the nature of the decision-making power given to participants. This implies that it is necessary to determine, during the implementation of a participatory structure, what type of decision-making power should be attributed to this new structure, as well as the respective weight of each individual or group within that entity. Clearly, for this pre-project, the authorities have not explained this point to either the resident committees or the inhabitants. In that sense, the case of the Tianzifang neighborhood in Shanghai is unique in China and could be a source of inspiration for Caoyang, at least for the *Neighborhood 1*. Actually, Tianzifang, a neighborhood with an industrial heritage, was rehabilitated by its own inhabitants, who converted it into a mixed residential and commercial area where tourists and residents peacefully coexist (Leroux et al. 2011).

18.5 Conclusion

Finally, based on the example of studies focusing on participatory approaches in Africa, the authors may draw the same conclusions as Jaglin: "*in opposition to the dominant discourse on the issue, fuelled by an idealized view of participatory management, our assumption is that current African experiences are more concerned about including the poor – or a fraction of them – in the deal, than promoting a democratic urban governance, ensuring the representation of pluralistic and often antagonistic interests*" (Jaglin 2005). The case under review in this paper, the introduction of a participatory process in an urban planning project in Shanghai, shows that these approaches could be used as a means to foster local governance and to legitimize the project. All the more as can be seen from the growing interest of Chinese authorities for this type of participation. For instance, Hu Jintao (2012) in his last speech at the 18th National Congress of the Communist Party of China on November 8, 2012 stated that: "*We should work harder to enhance socialist democracy in a systemic way by adopting due standards and procedures, expand people's orderly participation in governance at all levels and in all fields, and ensure that all governance functions are performed in accordance with the law*". Therefore, in the case of Caoyang, the next steps could be the implementation of a genuine pre-project with the launch of a questionnaire-survey at a larger scale and with a scientific rigor in order to measure the inhabitant's perception of their involvement. This would be the opportunity to find some peculiar qualitative indicators adapted to the Chinese urban context. The assessment of participatory processes is often limited to cross-referencing major quantitative indicators (sample, number of respondents, etc.) with a few qualitative ones (representativeness in terms of gender, ethnic origin, etc.). Yet, the tools that sociology offers provide the means to review these processes and to try to decipher what "is hidden behind the figures" (Hugrée and Kern 2008), a way to adapt the Chinese ladder to the urban context in order to improve the participation of inhabitants in a redevelopment project in an urban area, to fully involve them in the decision-making process, to better understand the social and economic contexts and then, to considerably foster local governance.

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Chapter 19
On Fast Transition Between Shelters and Housing After Natural Disasters in Developing Regions

Gary S. Prinz and Alain Nussbaumer

Abstract This paper presents the findings from an international workshop that brought together various NGOs, rebuilding coordinators, private sector leaders, engineers, and academics to discuss methods and issues related to fast reconstruction in developing regions affected by natural disasters. Natural disasters in developing regions often destroy homes and, together with economic conditions, force people to live in temporary shelters such as tents. Experience shows that rebuilding is often a long process because of issues related to land rights, evacuation of debris, standing building safety, coordination between local authorities, government organizations and NGO's, etc. In order to debate on the matter, the following themes were selected for the workshop: (a) Stimulating local economies, involving the local unskilled workforce. (b) Meeting basic needs, fast and safe rebuilding with appropriate materials; particularly considering the use of steel as a building material. (c) Adaptable construction, ways between affordable transitional shelters and sustainable long-term housing. Discussions on these three themes led to consider the particular problematic of rebuilding in urban settings. Fast rebuilding technologies suitable for high-density urban environments are needed, as well as strategies for implementing such technologies in environments where construction methods are tied to habit. In this context, the idea of promoting a multi-story, multifamily, locally fabricated shelter concept for fast rebuilding in urban environments is explained.

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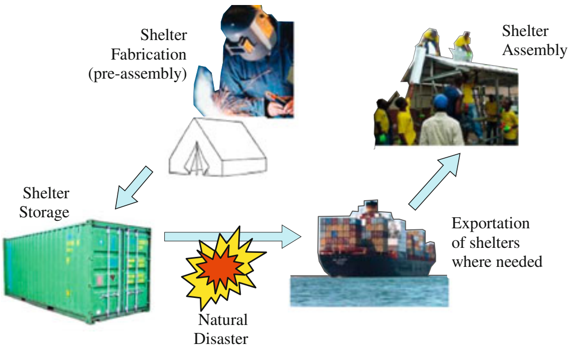
19.1 Introduction

Natural disasters in developing regions often destroy homes and along with economic conditions force people to live in temporary shelters. After the 2010 magnitude Mw7.0 earthquake in Haiti, over 1.2 million Haitians were displaced from their homes, many seeking shelter in makeshift tents or “shanties” (Margesson and Taft-Morales 2010). During that same year, massive flooding in Pakistan covered one-fifth of the country, affecting over 20 million people and forcing millions into temporary shelters (Guha-Sapir et al. 2011). In 2004, a magnitude Mw9.0 earthquake and subsequent tsunami devastated the west coast of Sumatra, Indonesia, displacing over 500,000 people from their homes (Meisl et al. 2006). With the relative frequency of natural disasters and the massive number of affected persons, strategies for fast reconstruction of shelters on a massive scale need to be developed: (1) to prevent relief organizations and governments from becoming overwhelmed as disasters reoccur during a project timeline, and (2) to quickly restore livelihood of the affected population.

When disaster situations affect developing countries, such as the Haiti earthquake, Pakistan floods, and Sumatra tsunami, the current status-quo for shelter relief is to import pre-assembled tents or tarp materials to accommodate immediate shelter needs. Following this emergency phase, organizations often construct individual “transitional shelters” aiming to restore livelihood and provide a shelter which has the potential to evolve into permanent housing. This typically involves providing a structural frame and basic covering (plastic tarp, etc.) that the individual owners then work to improve over time, transitioning into permanent housing. Due to issues related to land-rights, rubble removal, and coordination between local, governmental (GOs) and non-governmental organizations (NGOs), transition between temporary/evolving shelter and permanent housing is often a long process taking several years (Shelter Centre 2011). Figure 19.1 illustrates the fabrication, storage, transport, and distribution scheme for emergency shelters commonly used in disaster situations. From Fig. 19.1, supplying emergency shelter aid involves storage and transport of many large preassembled products

Fig. 19.1 Typical emergency shelter scheme



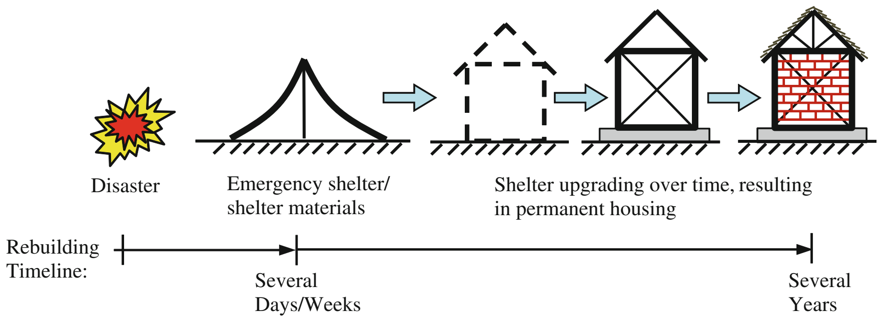


Fig. 19.2 Typical transition to permanent housing following disaster

which, depending on the proximity between the country supplying aid and the country receiving aid, could involve long distances. Figure 19.2 illustrates a typical evolution between shelter and permanent housing, based on the transitional approach proposed in the *Transitional Shelter Guidelines* (Shelter Centre 2011). This shelter process is often not necessary in developed countries (see cases from the Japan, Chile, and New Zealand earthquakes) where sufficient infrastructure is already available to aid the displaced population during rebuilding.

Rebuilding efforts in densely populated urban environments pose particular issues, one of which is land overcrowding from the displaced population (Rencoret et al. 2010). Rebuilding in densely populated environments requires significant pre-planning at the government and local level prior to reconstruction, including preparation of utility lines, and services. Initial emergency relief efforts in the densely populated city of Port-au-Prince following the 2010 Haiti earthquake created refugee-like camps, providing tarp and tent-like structures to meet temporary shelter needs; however, more than 2 years later, rebuilding efforts are still underway with many Haitians still displaced and living in a 'temporary' shelter situation (Booth 2012). Figure 19.3 shows a "tent city" camp in Haiti following the 2010 disaster (US DOD 2012).

Rebuilding efforts that span several years affect both the life and live-livelihood of the displaced population and can exacerbate often poor economic conditions. Additionally, corruption during construction and during governmental processes can affect shelter quality and inhabitant quality of life. Solutions that facilitate fast rebuilding, stimulate the local economy, and eliminate avenues for corruption are needed.

To develop ideas related to fast rebuilding and to discover further reconstruction issues, an international workshop was organized in September 2011, bringing together key players in the rebuilding process. Participants in the workshop originated from all over the world, including: Haiti, South Africa, Brazil, Columbia, India, the United States, and Switzerland. The workshop was organized by the Steel Structures Laboratory (ICOM) at the Ecole Polytechnique Fédérale de Lausanne (EPFL), envisioning steel as an interesting material for fast rebuilding. This paper presents the key findings from the workshop and expands upon

Fig. 19.3 Port-au-Prince, Haiti, "tent city" following the 2010 earthquake (Reprinted here with kind permission US DOD 2012)

presented ideas to develop strategies for fast rebuilding. It begins with a brief overview of the workshop participants, followed by the key findings from discussions on fast transitions between shelters and permanent housing. Next, particular issues related to rebuilding in urban environments are discussed and a multi-purpose, multi-story, multi-family shelter concept is presented. Lastly, conclusions are provided.

19.2 Overview of FAST Rebuilding Workshop

The workshop brought together multiple sectors having various interests and experience in reconstruction, including: private sector leaders, NGOs, academics, engineers, and rebuilding coordinators, to discuss methods and issues related to fast reconstruction in developing regions affected by natural disasters. Around 20 people attended the different sessions of the workshop. To stimulate debate, the following themes were selected for discussion:

- **Stimulating local economies**, involving the local unskilled workforce
- **Meeting basic needs**, fast and safe rebuilding with appropriate materials; particularly considering the use of steel as a building material.
- **Adaptable construction**, ways between affordable transitional shelters and sustainable long-term housing.

Table 19.1 presents a list of participating organizations and the following paragraphs present of summary of the key findings from the workshop presentations and discussions.

Table 19.1 FAST Rebuilding workshop participating organizations

Participating Organizations	Industry
Shelter Centre:	NGO
MEDAIR:	NGO
Project 16/6 Haiti:	Government (Haiti)
Swiss Humanitarian Aid Unit:	Government (Swiss)
InterTronco, SA:	Private Industry
Various:	Engineers/Architects
Indian Institute of Technology, Gandhinagar:	Academic/Research
University of Stellenbosch:	Academic/Research
Universidade do Estado do Rio de Janeiro:	Academic/Research
Institute of Construction and Infrastructure Management, ETHZ:	Academic/Research
Steel structures Laboratory, EPFL:	Academic/Research

Key findings:

1. Housing reconstruction must be resistant to future disasters and engage the local workforce. Between 2000 and 2009, 79 % of disaster casualties resulted from earthquakes and storms (EM-DAT 2010). Precautions must be taken in the rebuilding process to protect shelters against these recurring events. These precautions must be understood during the construction process and be implemented at the grass-roots level by individual owners (they will ultimately be responsible for sustaining and repairing the shelters). The individual owners must understand that little details can make the difference between a resistant and non-resistant structure (i.e., connection ties, bracing types, etc.). The overall consensus during the workshop indicated that shelter systems must engage the local work force during construction, through training and skill building. Mr. Clement Belizaire, project coordinator for the 16/6 project in Haiti and participant in the workshop, emphasized that every Haitian man is potentially a mason, capable of contributing to the reconstruction effort. It was agreed that coordination with locals and local involvement during rebuilding can boost morale and improve quality of life. However, one drawback to implementing local unskilled labor is the time required for training and skill building. This goes somewhat against a fast rebuilding concept and puts more emphasis on the transitional shelter necessities (training people to evolve their own shelters). The definition of a transitional shelter and its functional lifetime was found to be an open debate between the NGOs.
2. Sustainable shelter solutions shall respect local construction methods and materials. It was an overwhelming feeling from the NGOs with extensive field experience, that introduction of new technologies as a means of permanent housing will ultimately result in abandonment of the shelter for more traditional construction methods. Inhabitants unfamiliar with the building technology will be unable to repair, modify, or enhance their shelter, and ultimately convert back to familiar practices. As a result, reconstruction efforts aimed at providing individual housing units must include the local inhabitants and consider local

traditions in the decision making process. It was discussed that implementation strategies for new technologies must begin at the grass-roots level, forming confidence and familiarity in the systems. This however takes significant time, again going against a fast rebuilding concept; however, one potential way to quickly introduce new technologies is through implementation of the technology into public buildings rather than individual houses (make the technology visible in everyday public life and let it trickle into private life and private dwellings).

3. Scientific tools such as life-cycle assessment (LCA) analysis can aid NGO's and relief organizations in determining suitable materials and technologies for affected regions. Recent LCA research by Wallbaum et al. (2012) investigated the sustainability of various construction technologies and materials currently used in individual housing construction. Figure 19.4 demonstrates a sample LCA ranking of sustainable building technologies (Wallbaum et al. 2012). From Fig. 19.4, steel does not rank very well among other bio-based materials for use in individual housing. The various NGO's attending the FAST Rebuilding workshop showed interest in the LCA method and emphasized the need for such tools addressing shelter construction technologies to aid in decision-making and provide justification for a chosen reconstruction path.
4. Fast rebuilding at the individual house level may not be the most sustainable solution. With issues regarding connection/organization of services and utilities, land use, transportation routes, shelter quality control, etc., quickly assembling semi-permanent shelters may complicate future efforts to install services. Discussion from the NGOs and government leaders with experience in recovery efforts emphasized the need for quickly assembled, self-erecting (no cranes), disaster resistant, multi-story buildings (2–4 story). Such buildings

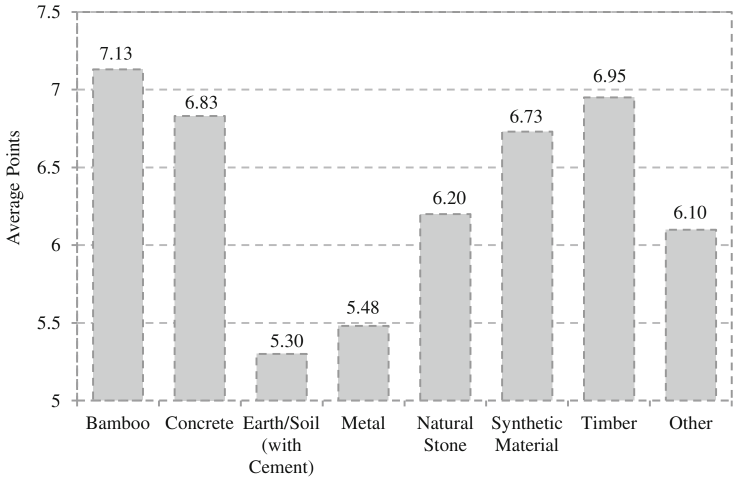


Fig. 19.4 Example LCA results per construction category (Reprinted here with kind permission Wallbaum et al. 2012)

could function as emergency shelters, they use less land, directly following the disaster, and transition (with or without relocation) into schools or office buildings once reconstruction efforts have progressed. In this respect, steel could be a good material, even if it is not locally produced, to be used in combination with other local materials (bamboo, concrete, etc.). Steel properties are advantageous for large construction and earthquake resistance, having both high strength and ductility. It was also emphasized that while introducing new technologies is difficult at the individual home level (people often feel comfortable with traditional techniques), multi-story shelters that transition into schools once rebuilding progresses could be the best way to introduce new building technologies to developing communities.

5. Discussions with the NGOs and humanitarian aid organizations noted that rural strategies often fail in an urban environment, and indicated a need for new urban methods.

19.3 Particular Problematic of Urban Settings

Reconstruction in urban settings poses particular challenges due to population density, building congestion, and integrated utilities and services (Rencoret et al. 2010). Individual single-story, single-family transitional shelters are well suited for rural environments having abundant space; however, in urban environments with a dense population of displaced persons and limited space, individual family shelters are impractical and can overcrowd land area slowing down the reconstruction effort. Unfortunately, currently used shelter systems are often limited to a single story, requiring large land area to accommodate a large population. Additionally, restoring services, such as access to clean water and sanitation in densely populated areas requires land availability. During the early stages of disaster relief, land area must also be available for clearing of debris (often large quantities of debris from congested building environments). Following the 2010 Haiti earthquake, unofficial settlements, “tent cities”, filled the open land space within Port-au-Prince complicating transportation and rubble removal efforts. Figure 19.5 shows the vast quantities of debris from the destroyed urban environment of Port-au-Prince, Haiti, and illustrates the complexity of rebuilding in an urban setting (IFRC 2012).

19.4 Multi-Story, Multi-Purpose, Multi-Family Transitional Shelters

In the context of an urban setting, it seems practical to develop multi-story (2–4 story) transitional shelters that accommodate multiple-families and free-up land for rebuilding of services, utilities, and clearing of damaged infrastructure.

Fig. 19.5 Urban destruction following 2010 Haiti earthquake (Reprinted here with kind permission IFRC 2012; photo credit Eric Quintero)

The multi-story shelters could initially serve as emergency shelter and slowly transition to function as public buildings (schools for example) once rebuilding has progressed. There also exists the possibility to upgrade the shelters into permanent apartments, or dismantle them if no longer needed. This concept could help to solve the issue of land rights, which commonly slows down rebuilding efforts, as the structure may ultimately belong to the community or government. A multi-story shelter, in which multiple families are housed in a single structure, require a multi-disciplinary approach between construction coordinators and water, sanitation, and hygiene programs (WASH for example) during the construction process. With WASH, multi-story, multi-family, shelters may improve efficiency, as only one person per building could be required to maintain the sanitation, water, and hygiene systems for all occupants. Additionally, the direct involvement from government decision makers and local community leaders would be encouraged as the constructed structures are intended to transition into government or community buildings.

Based on discussion between the FAST Rebuilding workshop participants, shelter systems using locally produced structural elements are desired over systems using imported structural elements. Using locally produced elements in the multi-story shelter design could: (1) engage local manufacturing and local workforce in the reconstruction effort helping to stimulate the local economy, (2) reduce construction time leading to faster rebuilding, and (3) could provide avenues for integrating new technologies into regions where traditional, inadequate, building methods dominate.

A promising solution for locally constructing multi-story shelters is to use multi-purpose structural elements along with special end connectors. A multi-purpose structural element is one that is currently locally produced for an application non-related to the shelter construction, but whose mechanical properties are well suited for carrying structural loads. In general, the multi-purpose shelter elements must be low-cost, lightweight, quickly and easily fabricated at an

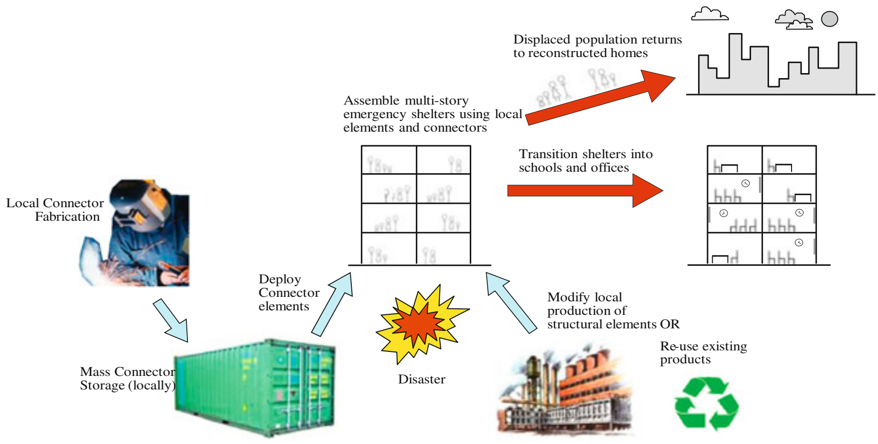


Fig. 19.6 Multi-purpose, multi-story, multi-family, shelter concept

industrial scale, durable, and have good structural properties to allow construction of multiple stories. Example multi-purpose elements include: steel angles, channel sections, cables, or light-gauge steel tubing (from ventilation ducts, signposts, or used drill piping), often found in developing regions. Used in combination with stored special end connectors, such elements could be used to erect large structural systems without the need for fasteners or cranes. Many existing scaffolding systems use this same concept. Figure 19.6 illustrates the multi-story, multi-purpose, multi-family shelter concept and Fig. 19.7 shows two sample multi-purpose element structure configurations.

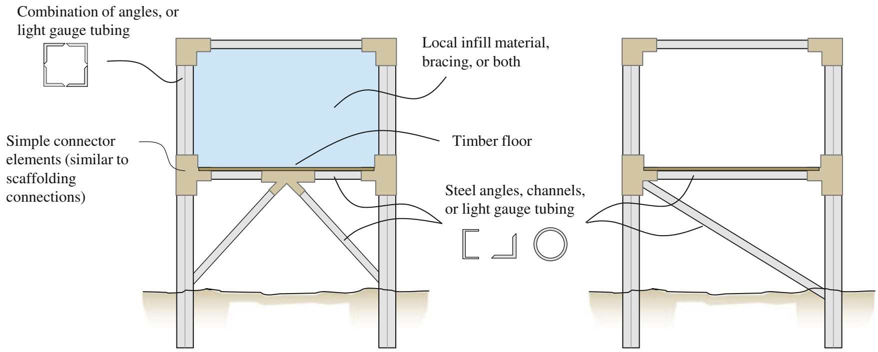


Fig. 19.7 Example multi-purpose element shelter configurations

19.5 Summary and Conclusions

This paper presents the findings from an international workshop on fast rebuilding which brought together leaders in the field of reconstruction following disasters. The workshop prompted particular focus on the problem of reconstruction in densely populated urban environments. The workshop inspired ideas related to local fabrication of multi-story shelters which were presented. The following are conclusions from the international workshop on fast rebuilding:

1. Housing reconstruction must be resistant to future disasters and engage the local workforce. Natural disasters (especially weather related ones) are usually recurring events and reconstruction must ensure improvement of performance/resistance.
2. Sustainable shelter solutions will respect local construction methods and materials. Ultimately, local inhabitants will adapt, repair, and improve their shelter and unfamiliar construction techniques will result in abandonment of the shelter for more traditional construction.
3. Existing research tools, such as LCA, may be useful to relief organizations in helping to determine suitable construction approaches.
4. A multi-story shelter concept to house multiple families may be a better approach in urban environments, and using locally produced materials and no fasteners or complicated assemblage in such structures may help to: (1) stimulate local economies (by engaging the local workforce and industry), (2) allow much needed space for reconstruction of damaged structures and utilities, and (3) provide an avenue for introducing new technologies (by using the multi-story shelters as public buildings following their emergency function).

Acknowledgments The authors acknowledge contributions made to the FAST Rebuilding Workshop by Professor Pedro Vellasco, Professor Jan Wium, and Professor Amit Prashant who all served as session chairs. Workshop contributions made by the individual session presenters from academia, government, NGO's, and private industry, are also acknowledged.

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Part IV
Technology Transfer or Co-Creation? Knowledge Sharing and Empowerment

Chapter 20
Research and Innovation for Sustainable Development

Luc Soete

Abstract Our understanding of the relationships between research and innovation has radically changed over the last 25 years. The implications for development are striking. They bring to the forefront the importance of endogenous innovation processes in both developed *and* developing country situations. In the old industrial Science and Technology (S&T) model, the focus in the context of development was on technology transfer and *imitation*—imitation to some extent as the opposite of innovation. In the new model, every innovation now appears unique with respect to its application. The re-use and re-combinations of sometimes routine, sometimes novel pieces of knowledge are important, but their successful application involve more engineering expertise and design capabilities. The feedback from users and design developers upstream towards more applied research assistance is an interesting example of reverse transfer of technology, from the South to the North, re-invigorating the research community in the developed world increasingly 'in search of relevance'.

20.1 Industrial Researchand Innovation in the Developed World

There has been a significant shift in the understanding of the relationships between industrial research, innovation and development, as has been acknowledged by many innovation studies scholars, ranging from economists such as David and Foray (2002) to Science and Technology Studies (STS) scholars such as Mike Gibbons (Gibbons et al. 1994) and Helga Nowotny (Nowotny et al. 2001). It is interesting to note that both the more economically embedded innovation research community as well as the more STS embedded research community have more or

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less converged on this issue; in each case the perception of the nature of the innovation process has changed significantly.

Innovation capability is now seen less in terms of the ability to discover new technological principles, but more in terms of the ability to exploit the effects produced by new combinations. Here one is reminded of Schumpeter's old notion of *neue Kombinationen,* and the use of pieces from the existing stock of knowledge (David and Foray 2002). This alternative model, which is closely associated with the emergence of numerous knowledge 'service' activities, implies a more routine use of an existing technological base allowing for innovation without the need for particular leaps in science and technology, sometimes also referred to as 'innovation without research'.

This shift in the nature of the innovation process implies a more complex structure of knowledge production activities involving a greater diversity of organizations whose explicit goal is knowledge production. The old Science and Technology (S&T) industrial system was based on a relatively simple dichotomy between knowledge generation and deliberate learning taking place in Research & Development (R&D) laboratories, including engineering and design activities, and activities of production and consumption where the motivation for acting was not to acquire new knowledge but rather to produce or use effective outputs. As David and Foray (2002) have argued, the collapse of this dichotomy has led to a proliferation of new places having as an explicit goal the production and use of new knowledge that may not be readily observable from national R&D statistics but which appear nevertheless essential to sustain innovative activities in a global environment.

This more recent mode of technological progress associated with the knowledge paradigm and the service economy, is based on flexibility, and is confronted with intrinsic difficulties in replication. Extreme forms include the attempts at ICT-based efficiency improvements in the financial and insurance sectors, the wholesale and retail sectors, health, education, government services, business management and administration. Learning from previous experiences or from other sectors is difficult and sometimes even misleading. Evaluation is difficult because of changing external environments—over time, among sectors, and across locations. It is often impossible to separate out specific context variables from real causes and effects. Technological progress will increasingly be based on trial and error, yet without—as in the life sciences—providing 'hard' data that can be scientifically analyzed and interpreted. The result is that technological progress will be less predictable, more uncertain and ultimately more closely associated with entrepreneurial risk taking. Attempts to reduce such risks might involve, as Von Hippel (2005) has argued, a much greater importance given to the users, even in the research process itself.

In this new mode of technological progress, a national R&D investment target not only appears odd from the analytical economic perspective, as discussed above, but it also makes little sense within a global knowledge world in which private R&D has by and large become a mobile production factor, with firms locating such activities where local conditions appear optimal. The most important factors in this regard include a sufficient supply of highly qualified human resources particularly in science and engineering, the availability of a public research base that is flexible and sufficiently open to interactions with the private sector, and a local environment characterized by a dynamic entrepreneurial culture, particularly with respect to potential suppliers and users. These appear to some extent the crucial ‘attractor’ factors that domestic policy makers need to address.

20.2 From Innovation for the Tip to the Bottom of the Income Pyramid

In many ways, the focus of industrial research and innovation in the developed world has been on continuous quality improvements of existing and new consumer goods, enlarging continuously the demand for such quality improved or new consumer goods. It formed the basis of the growth model as it emerged over the post-war period in the US, Europe and Japan which generated its own infinite demand for more material consumer goods. A continuous growth path of rising income with increasing consumer goods’ production *and* consumption (Pasinetti 1981). The continuously rising industrial R&D efforts in high-income countries appeared to match perfectly the continuously rising incomes of the citizens of those countries leading to a continuous enlargement of their consumption basket with new, better designed or better performing products. The initial demand for such quality improvements often arose from extreme professional, sometimes military use circumstances, but thanks to the media—which typically would emphasize the prestige image of such professional use using symbol figures such as sport athletes or movie actors—the average, non-professional consumer could easily become convinced that he or she was also in need of new goods with such technologically sophisticated professional quality characteristics even though those characteristics might ultimately add only marginally to one’s utility.

In a certain way the highest income groups in society, the “***tip***” of the income pyramid, acted often as first, try-out group in society, contributing happily to the innovation monopoly rents of the innovating firm. Therefore, a continuous circle of research was set in motion centering on the search for new qualitative features[1] to be added to existing goods. This “*professional-use driven*” innovation circle has been the main source for extracting innovation rents out of consumer goods—ranging from consumer electronics, sport goods, shoe wear, household equipment, computers, mobile telephony, medical diagnostics, sleeping comfort, and so on—with a “too long” *physical* life time. The worldwide risks of this relatively straightforward professional-use driven innovation strategy for the existing global multinational corporations have increased significantly, not in the least because of

[1] One may think of audio and sound, vision and clarity, miniaturization and mobility, weight and shock/water resistance, feeling and ergonomiticity, etc.

globalization. While the world market for new innovative goods appears at first sight gigantic and without any doubt sufficient to recoup investments relatively quickly, the huge research, development, prototype and global marketing costs, coupled with ever-increasing numbers of competing international players means that the length of time that a company can enjoy its innovation rents is diminishing very rapidly. Hence, despite the growing high-income classes in the large emerging BRIC economies, the new generation of goods being sold to the emerging high income classes in those countries will be insufficient in actual earning opportunities to fund both the shift towards mass production and the development of the next technology generation of the good in question. Having developed incredibly sophisticated technologically new goods, many firms are encountering global sales problems over a much contracted product life cycle with increased competition and rapidly over-saturated markets.

The need for a shift in research on innovation in private businesses away from such conspicuous innovation has been popularized by CK Prahalad in his famous book: The Fortune at the Bottom of the Pyramid (2005) with the provocative subtitle "*Eradicating Poverty through Profits*". One of the best-known Prahalad examples of a Bottom of the Pyramid (BoP) innovation is the multiple-fuel stove innovation developed for the rural poor, in which cow dung and biomass (sticks and grass) can be used as cooking fuels. Traditionally these fuels are used in an extremely inefficient way and are dangerous to use due to the smoke inhaled from indoor fires. Since the book of Prahalad, there has been a flood of similar examples of BoP innovations being primarily introduced by foreign, large multinational corporations from developed countries in developing countries, sometimes in poor rural villages, sometimes in urban slums (for some of those examples in the sanitation area, see Ramani 2008). This is where BoP innovation takes on, in the author's view, a new meaning in line with its creative destruction nature.

In this sense, the notion of "*grassroot innovation*" can be considered as the endogenous, intrinsic version of Prahalad's external, top down version of BoP innovation. The innovation process is now in the true destructive creation sense likely to be reversed, starting with the design phase which will be confronted directly with any attempt at finding functional solutions to some of the particular BoP users' framework conditions. This will involve not just the need to bring the product on the market at a substantially lower price than existing goods, as Prahalad emphasized, but also a clear adaptation to the sometimes poor local infrastructure facilities with respect to energy delivery systems, water access, transport infrastructure, digital access, etc. *Autonomy* is the key word here. It is no surprise that the most rapidly spreading technology in developing countries has been mobile communication with currently more than three billion users worldwide. Autonomy from high quality energy, water, broadband network availability is undoubtedly one of the most pervasive drivers for BoP innovation.

Another one might well be "*cradle to cradle*" sustainable innovation (McDonough and Braungart 2002, 2011). The lack of high quality logistic infrastructure facilities in rural development settings might well imply that once goods are sold, the repair and/or central recollection of obsolete goods or their parts will be particularly expensive. By contrast, local re-use along the principles of cradle-to-cradle might well be a new form of sustainable grassroot innovation.

20.3 Innovation for Development: The New Challenges

The implications of this new mode and prioritization of technological progress for development are rather striking. Suddenly they bring to the forefront the importance of endogenous innovation processes in both developed *and* developing country situations. In the old industrial S&T model, the focus in the context of development was quite naturally on technology transfer and *imitation*—imitation to some extent as the opposite of innovation. In the new model, innovation is anything but imitation. Every innovation now appears unique with respect to its application. Re-use and re-combinations of sometimes routine, sometimes novel pieces of knowledge are likely to be important, but their successful application might ultimately involve engineering expertise, design capabilities and even research.

As in the 1970s when the first cases of successful and failed innovations in developed countries were being collected (by the project SAPPHO at the Science Policy Research Unit, University of Sussex; see Rothwell et al. 1993), there seems now an urge to collect as many cases as possible of such BoP innovations so as to understand better the complex characteristics of such innovations for development. On a speculative note, let me add some observations on likely conditions for successful innovation for development. First, following the new innovation mode described above, the likely and most successful location of BoP innovation activities will be close to BoP users' contexts (Ghosh and Soete 2006). If one is to believe the crucial role of users in the innovation and subsequent research process, in the case of BoP research, this will involve BoP users. The role of local communities of increasingly professionalized non-governmental grassroots organizations will be often crucial here. The most interesting and exciting new developments might well consist of new strategic alliances emerging between NGOs and multinational firms in the development of BoP laboratories that are embedded in such environments and are not part of traditional high-tech R&D centers or enclaves in developed or developing countries.

Second, and again following from the shift in the research paradigm described above, in the case of innovation for development, the innovation process itself is likely to be reversed, starting with the design phase, which will be confronted most directly with the attempt to find functional solutions to the framework conditions of BoP users. This process will involve not just addressing the need to bring products to market at prices substantially lower than those of existing products, as Prahalad noted, but also a clear adaptation to poor local infrastructure or facilities, such as energy delivery systems, water access, transport infrastructure or digital access. It is in this sense that one might talk about "*appropriate innovation*" and that there seems to be some analytical similarity with the old notion of "appropriate technology".[2]

The feedback from BoP users and from design developers upstream towards more applied research assistance, even fundamental research in the core research labs of Western firms, is possibly the most interesting new example of reverse transfer of technology (from the South to the North), re-invigorating and motivating the research community in the highly developed world increasingly 'in search of relevance'.

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[2] The notion of appropriate technology was of course much more formalized in terms of a rational set of economically determined "choices of technique" (Sen 1968), depending very much on capital-labor substitution possibilities. The term "appropriate innovation" by contrast is much more open.

Chapter 21
Appropriate Technology to Reduce Risks and Protect Assets: An Example from Development Cooperation in Bangladesh

Nicole Clot

Abstract Recent disasters have revealed how risks are highly linked to existing development gaps, weak and inappropriate technologies as well as growth in economic and population exposure. Technology choices can contribute to risk reduction, but can also significantly increase and create risks. Especially in the two projects of the Swiss Agency for Development and Cooperation (SDC)—*Livelihoods, Empowerment and Agroforestry (LEAF)* and *Samriddhi*—HELVETAS Swiss Intercooperation as implementing agent has started to systematically apply Disaster Risk Reduction (DRR), so the identification of appropriate technology was key. Although it is widely acknowledged that structural measures shall be based on local priorities, such measures today are often donor-driven and stand-alone interventions instead of being part of an integrative holistic approach. The paper focuses on the question how do we define appropriate technology by referring to the expensive flood protection measures by the World Bank (WB), who was asked by the government to develop the Flood Action Plan (FAP), after the successive floods in Bangladesh in the 1980s and 1990s. In the flood-prone area of Sunamganj (the project region), flood protection measures in the form of massive protection walls were built around the *hatis*. These walls became the most visible and aspired measures against flood so that communities stopped their traditional practice. The faith in such traditional technologies eroded over time as communities waited for these protection walls to be built and the precarious *hatis* continued to erode causing loss of life and property including negative impacts on various livelihood activities in each successive monsoon season.

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21.1 Introduction

Across the world, large populations are increasingly exposed to the risks of multiple and recurrent "natural"[1] disasters that reverse decades of development work, slowing down progress towards poverty reduction. Recent disasters demonstrated that such risks are often constructed through existing development gaps, weak and inappropriate technologies and growth in economic and population exposure (UNISDR 2011). Poverty and vulnerability to disasters are closely linked: low-income countries and with them, the poor and disadvantaged groups are typically more vulnerable to and disproportionately affected by disasters (IPCC 2012). Poverty reduction, sustainable development and Disaster Risk Reduction (DRR) are closely interlinked and interdependent objectives. The Hyogo Framework for Action 2005–2015 (HFA) is the international response to reduce vulnerabilities to natural hazards and assists the efforts of nations and communities to become more resilient to and cope better with the hazards that threaten their development gains (UNISDR 2005).

Even if natural hazards cannot be fully avoided, disasters to a large extent can be avoided by reducing the exposure of communities to the hazard, increasing their capacities to withstand it and/or by reducing their vulnerability (UNISDR 2005; 2009). The application of appropriate technology is a crucial measure that development cooperation can bring in and can contribute to improving the economic and social resilience of a community (Murphy et al. 2009).

The main question is therefore how do we define appropriate technology and what makes it successful? The term originally referred to technologies almost entirely used in developing countries. In a broader sense, it also includes the less tangible aspects such as knowledge transfer mechanisms, social, cultural, and gender issues (Murphy et al. 2009).

It is widely acknowledged that in the context of appropriate technology, the role of local knowledge and practices is crucial. Although evidence has grown that local knowledge and practices can help development organizations to improve disaster preparedness activities (ICIMOD 2007; Huggel et al. 2008) and that aid alignment must in general be based on locally determined prioritization (CCD Commission 2008), structural[2] measures today are often still donor-driven and thus the question of ownership is still very problematic. Further, structural measures are often stand-alone interventions instead of being part of an integrative and holistic approach. Risk management cannot be viewed in isolation from other

[1] Disasters are a complex mix of natural hazards and human action. Indeed, a crucial point about understanding disasters is that they are not purely the results of natural events, but the product of social, political and economic context in which they occur.

[2] Structural measures or so-called hardware are any kind of physical construction to reduce possible impacts of hazards or engineering techniques to achieve hazard-resistance and resilience in systems (UNISDR 2009).

pressures of development, but should rather be part of an integrative effort towards reducing vulnerability and promoting livelihood resilience (Few et al. 2006).

The present paper illustrates one example of combining traditional knowledge with external resources and knowhow and the social process to develop appropriate technology. It shares some of the lessons learned from HELVETAS Swiss Intercooperation[3] experience in the projects of *Livelihoods, Empowerment and Agroforestry (LEAF)* and *Samriddhi* by the Swiss Agency for Development and Cooperation (SDC) in the flood-prone area of Sunamganj in Bangladesh.

21.1.1 Context

21.1.1.1 The National Context: A Retrospection

Bangladesh is a highly flood prone country and its destiny has been shaped by floods, both constructively and in the form of devastating, recurrent events. Once every ten years about one third of the country is affected by floods; in catastrophic years like 1988, 1998 and 2004 more than 60 % of the country was inundated (CEGIS 2002). Therefore, flood protection measures have always played an important role in Bangladesh's society, at the local as well as at the national and international level.

After the successive floods of 1954 and 1955, several studies were initiated on water resource management and much investment was made in flood control measures. The World Bank supported flood control measures to protect about 72,000 ha of land through the construction of large-scale embankments along the Jamuna (Brahmaputra) and Teesta Rivers. A second project was on combined flood control with dry season irrigation combining construction of polders with the installation of large-scale reversible pumps for drainage in the wet seasons. The maintenance of the embankments and the pumping equipment was a financial challenge from the start together with the challenge posed by the massive rivers that constantly changed their course.

The successive floods of 1987/1988 (magnitude of a 100 year event) triggered coordinated action by several donors and research organizations on multi-dimensional flood studies (Brammer 1990). In 1989, the G7 summit in Paris took note of the periodic flooding and its devastating impacts on Bangladesh and stressed the need for coordinated action. The Government of Bangladesh approached the World Bank to coordinate actions aimed at flood protection by the international community (Custers 1993). The Flood Action Plan (FAP) prepared by the World Bank had eleven guiding principles comprising land use management policies, flood plain zoning, protection of rural infrastructure, design of

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[3] HELVETAS Swiss Intercooperation is one of the most experienced and largest development organizations in Switzerland. For more information, see: www.helvetas.org

major communication infrastructure such that they do not impede the flow of flood waters, structural measures including embankments to channel the flow of flood water, etc. (WB 1990). In practice, however, the FAP ended up focusing largely on structural protection as a key component of a long term flood control program and mainly focused on riverine floods although Bangladesh is equally affected by flash floods and rainwater induced localized flooding (WB 2011). The increased volume of rainfall caused by climate change during the past decades has even intensified the flood problem and will be one of the major challenges for the country (IPCC 2012; Brouwer et al. 2007).

Besides the devastating impact floods have in the country, water resources respectively the wetlands in Bangladesh are one of the major sources of livelihoods particularly for cultivating food crops, vegetables, fishing and pasture lands. Bangladesh is estimated to possess seven to eight million hectares of wetland, i.e., about 50 % of the total national land (Islam 2010; Khan et al. 1994).

21.1.1.2 The Project Area

The working area of the two programs by SDC[4]—*LEAF* and Samriddhi[5] implemented by HELVETAS Swiss Intercooperation—is located in such a wetland area in northeastern Bangladesh[6], in the Sunamganj district. The area is marked by *haors*, bowl-shaped depressions between natural levees of a river subject to monsoon flooding and flash floods every year. The country has altogether 411 *haors* comprising an area of about 8,000 km^2 dispersed in the different districts (Sunamganj, Sylhet, Moulvibazar, Hobgonj, Netrokona and Kishoreganj) (Chakraborty 2005).

In the case of the project region, most of the area is inundated from May to October and people live on scattered small patches of artificially raised land, called *hatis*, which become islands during the rainy season and are particularly vulnerable to flooding and wave erosion (Fig. 21.1a,b). Each year flash floods, a sudden rush of rain and downstream water from the bordering hills in Meghalaya, India, affect this region and are of major concern to the communities as this type of flooding often implicates huge losses of crop, as they usually occur end of March just before the harvest season or in April during harvest.

Despite the economic importance of the *haors*, people in the region are poor as more than 28 % of the total population lives below the national Lower Poverty Line (LPL).

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[4] For more information about the projects and SDC, visit the following websites: http://www.swiss-cooperation.admin.ch/bangladesh/; http://www.deza.admin.ch/ and http://bangladesh.helvetas.org/en/activities/

[5] The name of the project meaning "prosperity" in Bangladesh.

[6] The total project's working areas cover Rangpur, Bogra, Rajshahi regions in northwestern and Sunamganj district in northeastern Bangladesh; however, the focus in this paper will only be on the Sunamganj district.

Fig. 21.1 *Hatis* in the Sunamganj region (Reprinted here with kind permission, From. Intercooperation 2009). (a) Between November and March/April, (b) Between April and October

The main reasons of poverty are limited natural resources and the lack of infrastructure as well as limited access to services reinforced through the disastrous effects of natural extreme events (BHWDB 2010). An additional reason is the fact that people in the *haor* area can only grow one crop per year as for the rest of the year the land is under water.

While most of the FAP interventions focused on the river systems, some flood protection structures in the form of massive walls were also built around the *hatis* in the Sunamganj area. They were built by a multitude of organizations including International Non-Governmental Organizations (WB 2011).

In the project region, the massive flood protection walls became the most visible and aspired measure against flood. Communities stopped their traditional practice of raising a local grass (*challa bon*) to reinforce their settlements using a combination of such grass, earth and bamboo scaffolding. The faith in such traditional technologies eroded over time as communities waited for massive flood protection walls to be built around their settlements and the precarious *hatis* continued to erode causing loss of property and assets including livestock with negative impacts on various livelihood activities in each successive monsoon season.

The selection of appropriate technology in the region becomes even more prominent considering the adverse impacts of climate change. Recent studies clearly indicate an increased variability in the *haor*, especially flash floods are found to be more pronounced in those areas compared to earlier times (Sawon and Khan 2011; Government of Bangladesh 2005; Mirza 2002).

21.2 Design and Methods

While the programs of *LEAF* and *Samriddhi* have been effective in improving livelihoods and the economic status of households through a wide range of interventions such as floating gardens, home gardening, duck rearing, poultry (activities which are in line with other studies from the region, e.g. Sawon and Khan 2011), measures to address disasters, that negatively affected years of development work, were felt to be lacking. The project recognized that communities in the region incur significant coping costs to maintain and strengthen their homestead, ranging between US$150 and US$200 per household per year (Intercooperation 2009)[7]. The concept of DRR was therefore introduced and adopted as a transversal theme, with the support of SDC to increase the economic and social resilience of communities to natural hazards and to contribute to long-term development.

The participation of local stakeholders is key in the process of identifying appropriate technologies. For this reason, HELVETAS Swiss Intercooperation

[7] The examined damage costs in the feasibility study by Intercooperation in 2009 are in line with a study conducted by the Dutch Poverty Reduction and Environmental Management program for the same region which calculated about US$ 190 per household per year which corresponds to about one fifth of the total income (Aftab et al. 2006).

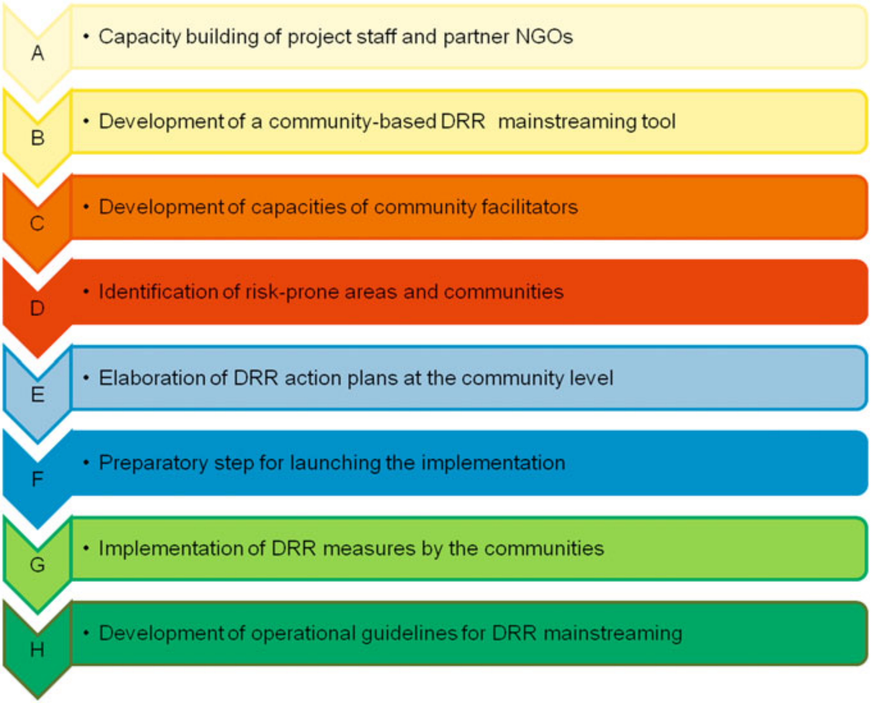

Fig. 21.2 The eight steps from piloting to mainstreaming DRR (reprinted here with kind permission from Intercooperation 2011)

developed a basic approach involving eight broad steps (Fig. 21.2) which led to the mainstreaming of DRR in the programs. The process includes awareness raising and capacity building activities as well as the steps of identifying risk-prone areas and of conducting a community-based risk assessment that led to the identification and implementation of specific DRR interventions. One such DRR measures was a community-based approach to revive traditional *hati* protection measures which is at the core of the present chap. However, it is important to emphasize that the aspect of *hati* protection is only one particular aspect which communities are concerned with as the impact of flooding as such has a major impact on all their livelihood activities.

The DRR interventions and its approach need to be seen in the context of the livelihood projects whose core activities are to build social and economic resilience, raise awareness and build capacities of stakeholders. Recognizing this fact, the involvement of local communities and authorities was crucial and at the core of all interventions. The projects' direct interlocutors are the Community Based Organizations (CBO), an established structure at the local level. The CBO are seen as the drivers for local development and play an essential role in building linkages and partnership with public and private organization, local governments and

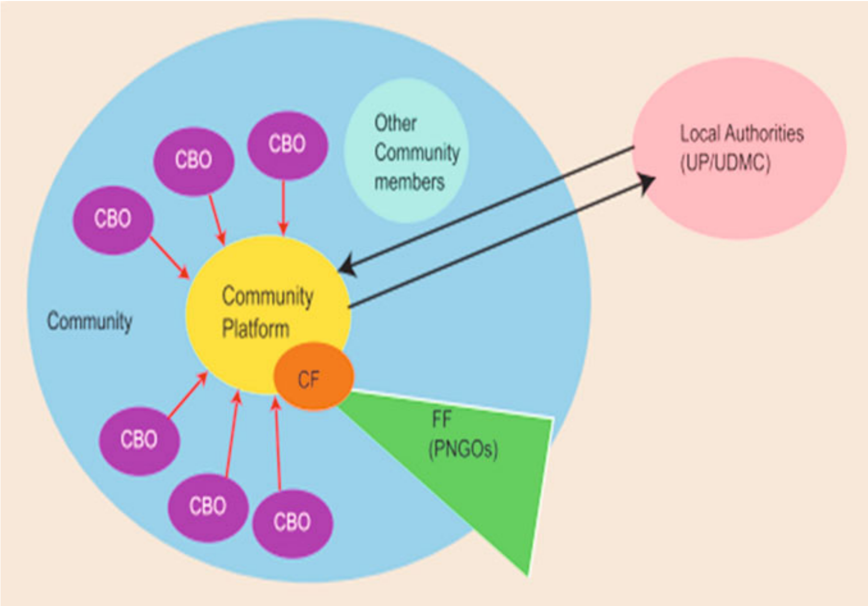

Fig. 21.3 Overview of actors at the local level (reprinted here with kind permission from Intercooperation 2011)

market actors (see Fig. 21.3). The CBO are located in a Ward within a Union; the Union with its *Union Parishad* (UP) and the elected UP members is the lowest tier in the local government structure. The UP itself has a *Union Disaster Management Committee (UDMC)*, a direct response of the *Comprehensive Disaster Management Programme of Bangladesh (CDMP)*, which shows the importance given to DRR in the country (MOFDM 2003, 2007; Clot and Carter 2009).

The direct collaboration with the CBOs ensured that all the interventions reflected community's needs and were accepted at the local level.

21.3 Results

In general, the DRR interventions have contributed to saving assets and homes and are well accepted by the community members and local authorities.

In this instance, a set of different capacity building training courses at various levels were conducted to help communities analyze and elaborate specific DRR measures, even after the phasing out of the project. Thus, skill building and knowledge sharing in combination with traditional good practices formed the bedrock of the appropriate technology. So the main question is therefore when do we talk about appropriate technology and what makes them appropriate?

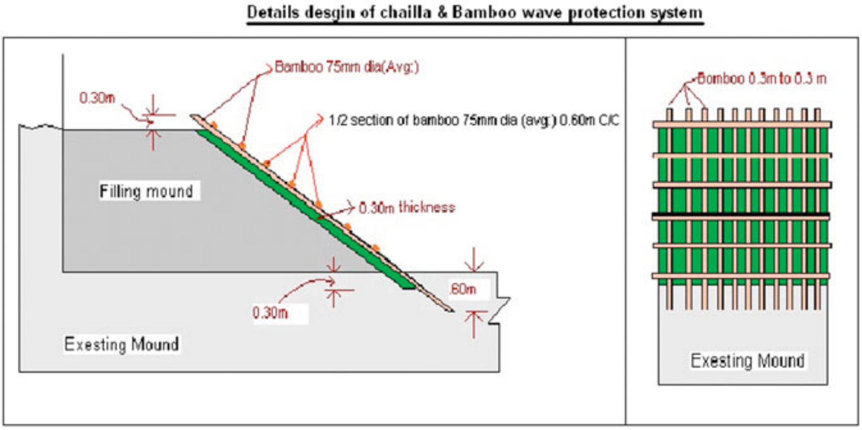

Fig. 21.4 Design of a *hati* (reprinted here with kind from permission HELVETAS Swiss Intercooperation, Zahid Hasan)

Using the example of *hati* protection, the present paper will present now the main lessons learned and challenges during the process of selecting appropriate measures and illustrate how HELVETAS Swiss Intercooperation deals with the question of appropriate technology.

The concept of 'smart hardware': While identifying possible DRR measures in the context of appropriate technology, the concept of 'smart hardware' was introduced. In the context of the programs, it refers to infrastructure measures that (i) protect assets or lives in case of a disaster, using local material and indigenous techniques with minimal external support; (ii) can be implemented and replicated by the communities; (iii) contribute to raising the awareness of the community about the importance of prevention and preparedness activities; and (iv) can be maintained by the communities without external support. In order to ensure ownership, the community was asked to contribute to the construction costs by donation of land, labor and/or construction material[8]. Further, 'hardware measures' were only introduced in synergy with software activities such as awareness raising, capacity training, collective action, etc. ('hardware serves as a means for software').

Revival of traditional and indigenous measures: Some of the important gains of the intervention were the revival of planting of *challa bon* grass in the dry season in areas surrounding the *hatis* (Fig. 21.4). In the past, there were specific areas in the *haor* region where *challa bon* grew and from where it was harvested by the communities. However over time, these areas were colonized for habitation and the *challa bon* plantations disappeared.

Scarcity of bamboo continues to be a problem. Bamboo is a multipurpose and versatile plant, providing a structural barrier against high winds, and material for

[8] Contribution by the communities is a conditionality of the project.

housing, fencing, basket weaving, etc. Given the increasing density of population in the *hatis*, there is not much scope to expand or intensify the cultivation of bamboo in the region. Purchase and transport of bamboo was one of the most important elements in the cost of the pilot activity. However, if the practice picks up, a supply chain for bamboo could emerge.

Multipurpose use of structural measures: Local acceptance is an important element for an appropriate technology. In the case of the *hati* protection, two particular points contributed to the reacceptance of the measures. In order to give the structure an appropriate slope, some additional earthwork had to be done so the *hatis* got some additional surface. The raised and extended *hatis* can now be used for Income Generating Activities (IGA) such as poultry and livestock rearing, vegetable cultivation, post-harvest management of rice and storage of livestock feed. *Challa bon* grass is also planted on this land and needs no longer be bought. The introduction of structural measures around the *hati* has multiple uses, reducing the impact of natural hazards while generating income during the dry season.

Thanks to collective effort, even the most vulnerable are now protected: Through the improved *hati* protection, the cost could be reduced for each household by about 25 % (Field visit to the community of Putia, Beheli Union, Jamalganj Upazila 2009). Poor and extreme poor households, who could not protect their homestead in the past, also benefit from this collective effort as the whole *hati* is protected. Measures that used to be adopted by each household are now done collectively, reducing both cost and time and contributing to better cohesion and more collective action within the community and above all, it particularly reduced the risk of devastating impacts on the *hati*.

***Hati* triggered a discussion about the appropriateness of technology and encouraged mobilization among neighboring communities:** The revival of the traditional *hati* protection also triggered a discussion about the appropriateness of technology among the neighboring communities in the region. Some of the nearby communities visited the pilot *hatis* in order to learn more about the rather low cost investment of *hati* protection in comparison to the well-known cement brick walls as the dominating infrastructure in the Sunamganj region. The simple measure was regarded as a good alternative to reduce the negative impacts of the recurrent floods and is indeed even in their own power to implement instead of waiting for a government program. The demand for such raised *hatis* was quite strong, not least because the extra space could be used for livelihood activities, in a region where space during the rainy season is very limited.

Self-help instruments at community level increase local ownership: To ensure that local needs are identified in a systematic and participatory way, the community-based DRR planning tool was developed[9] which turned out to be an

[9] The basis for the tool is the Community Risk Assessment and Risk Reduction Action Plan guidelines developed and used by the Government of Bangladesh (MOFDM 2005) and the Community-based Risk Screening Tool, Adaptation and Livelihood (CRiSTAL), developed by iisd, Intercooperation, IUCN and SEI. For further information and to download the tool: [http://www.iisd.org/cristaltool]

effective instrument to promote active participation and involvement of both the community and the local authority through the process of identifying, planning and implementing DRR measures in accordance to their needs and priorities (Intercooperation 2010). While the tool facilitates the elaboration of concrete DRR actions, increased awareness and capacities are additional benefits. Particularly promising is the active participation of community people in the planning process, which creates a sense of ownership for the implementation of measures.

The revival of traditional *hati* protection measures was a concrete outcome of an urgent local need identified by both the communities and local authorities during the process of the DRR planning. Recognizing the fact that they lost livestock and assets during the floods in recent years while waiting for flood protection, made them realize that they can reduce their vulnerability with their own resources.

To conclude, the example of the *hati* protection is one specific structural measure whose particular experience is shared in the context of appropriate technology. Nevertheless, it is worth mentioning that the people's livelihoods in this region (e.g., rice cultivation, fodder for their animals) are particularly vulnerable to floods and erosion and their income indeed is entirely shaped by the narrow window of opportunities for agricultural activities (November − April). In this regard, two more specific DRR measures, which have not been particularly considered in the present paper, are of crucial relevance: (i) embankments to protect their fields from early floods when rice is not yet harvested and (ii) the cultivation of early rice varieties that allow farmers to harvest mature rice before the critical period of flash floods. The saving of their rice harvest is of particular importance to the farmers as only one crop (*boro rice*)[10] can be harvested in this region. For this reason, HELVETAS Swiss Intercooperation in collaboration with the Bangladesh Rice Research Institute (BRRI) has introduced early rice varieties that allow farmers to harvest mature rice before the critical period of flash floods occurs (Intercooperation and Swiss Agency for Development and Cooperation 2011). Demonstration plots and trials for Participatory Variety Selection (PVS) were established. PVS trials on short duration rice proved that the rice could be harvested within 120 days, instead of 140–160 days. As a result of the trials, a short duration variety of rice (BRRI dhan 45) could be identified and harvested with a good yield before the flash floods (Intercooperation and Swiss Agency for Development and Cooperation 2011). Last but not least, the paddy cultivation as such is also an important source of labor and income for the many landless people in the region. The flash floods in 2010 clearly showed the vicious cycle of poverty: the damaged crop affected food availability, left the agricultural laborers without work and the animals starved to death, as not enough fodder was available so that the poor even fell deeper into the vicious cycle of poverty. The Government of

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[10] The *boro rice* is commonly known as winter rice. The term *boro* is Bengali originated from the Sanskrit word "*Boro*" which refers to a cultivation from November to May under irrigated condition (IRRI 2005).

Bangladesh mandated the Wetland Development Board (BHWDB) to coordinate and elaborate an integrated approach for maximizing the utilization of resources, both human and natural resources (BHWDB 2010).

21.4 Lessons Learned and Challenges

The insights derived from the concrete experience of implementing DRR measures in the livelihood projects in the flood-prone area of Sunamganj yield a number of lessons and challenges with regard to the implementation of appropriate technology.

21.4.1 Lessons Learned

While structural measures are needed to reduce vulnerability, the following set of principles should be considered in the selection: (i) cost effective structural measures which can be replicated by the community with no or little external support; (ii) ensure the community's own contribution and facilitate linkage with possible stakeholders; (iii) clarification of maintenance and costs as well as future responsibilities at the very beginning of the intervention; (iv) promote indigenous techniques and material. In the case of the project, the question of maintenance and costs is, however, seen as a particular challenge as it requires regular follow-ups by the projects to check how maintenance is managed by the local stakeholders.

Demonstration is key to mobilize communities to invest in preventive measures: Special attention should be given to the question of acceptance when introducing new (including reviving and/or) improved technology. In general, using local material and indigenous techniques as in the case of the improved *hatis*, was widely accepted by the communities in the project area. However, some additional efforts by the project was required to get the entire community involved including local investment in form of labor and financial resources. Besides a number of awareness raising and capacity building events, it has become evident that most such measures were only accepted and widely implemented when first successful results were achieved within their own or a neighboring community. Only then was the community convinced to go for such DRR measures. In the case of the *hati* protection, the convincing arguments were: the incurring coping costs could be reduced; the occurrence of the annual floods did not destroy the construction so that the protection material could be reused in the following year and thirdly the increase of income through the income generating activities introduced at the raised slope were arguments enough to get the communities convinced.

DRR measures should ideally be linked to income generating activities: It is worth mentioning that the DRR interventions among the community members were not equally accepted. Unlike other activities under the project, the "incentives" to get poor and extreme poor people involved might not be as obvious. When someone is surviving from day to day or week to week, DRR may be less of a priority than immediate food security. However, the involvement of poor and extreme poor people in DRR measures is an important step towards increased local resilience. In the concrete case of the livelihood project, the prevention and preparedness measures were not standalone interventions, but were linked to income generating activities (e.g., rice cultivation) or particular community work (e.g., landless help making embankments to protect the paddy fields). Although DRR means an investment in the reduction of potential risk, the communities clearly recognized the importance of investing in risk reducing measures in order to ensure their income generating activities.

Structural and non-structural measures need to go hand in hand: When introducing structural measures, it is crucial that they are well embedded at the local level and secondly go hand in hand with non-structural measures. In particular, vast infrastructure with huge investment (e.g., international organizations), may lead to stand-alone interventions where awareness raising and strengthening of capacity is often ignored. Such infrastructure often puts communities further at risk in the medium and long term and leads to dependency on external actors, kill indigenous technologies, knowledge and practices that have protected communities in the past. Further, they can also promote a false sense of security among the community so that people settle nearby the new infrastructure as they think it is safer; in short, such measures may even increase exposure and vulnerability over the longer term (IPCC 2012).

21.4.2 Challenges

Acceptance of smart hardware based on traditional techniques critically perceived: In the initial stages, the communities were quite reluctant to invest in recreating their traditional protection measures as they felt it would be labor intensive, time consuming and would require constant maintenance. A concrete wall was the aspired protection measure, as it did not demand any time or labor from the communities for construction or maintenance. The project had to explain to the communities that it did not have the resources or the mandate to build such walls and the only support it could provide to the communities was reviving the *challa bon* plantations, material support for the construction of the structures and help in organizing themselves for transport and the construction work. A community contribution was also sought in the form of labor contribution. After much discussion, the close-knit community came forward to participate in the *hati* protection pilot project.

A visit 6 months after the intervention revealed that that the *hati* protection helped in the prevention of wave erosion, created some extra space for the communities and the bamboo and grass scaffolding reinforced with earth was able to withstand the flooding and the wave erosion of the previous season. However, the structure required regular maintenance and here the community continued to expect support from others such as the local government and the project.

User groups—elected body (maintenance): The *hati* protection measures were undertaken by a set of households who came together to form a community based organization (see Fig. 21.2). The work was organized and undertaken with a lot of energy and enthusiasm, as it would directly benefit each of the participating households. In some communities, the collaboration between community and local government was not as encouraging as expected. In this case, the local government feels few or no ownership towards the structure, as they were not directly involved in the decision-making. Given that the protection measures require regular upkeep, the community would now like the local government to consider the structure under its plans for periodic infrastructure repair and reconstruction and allocate resources that they receive from higher levels of the government for this purpose. The local government is reluctant to do so arguing that it has limited resources and the maintenance of just one such structure may take up a large proportion of it. As an elected body, it seeks to ensure an equal distribution of resource among its constituency rather than a skewed distribution based on needs. The project emphasizes that the design of the structure is such that local communities have the resources, knowledge and means to take up the maintenance themselves. The project is aware about this particular challenge, but considers at the same time the involvement of the UPs in DRR interventions at the grassroots as key as the integration into (future) maintenance and protection plans of the UP could be encouraged. Even further, linking them better with the UDMC can increase sustainability. For this reason, the project team had the idea to formulate a kind of DRR Challenge Fund where it is a pre-condition that any proposal from the community has to be routed through the UP and UDMC in order to get their support and ensure proper follow-up.

Ownership by the community: Another challenge was the fact that the pilot program had to make sure that the activities were completed before the monsoon season starts. So full and prior community commitment to both construction and maintenance aspects were regarded as important, but could not be fully ensured in the end due to limited time before the monsoon season. Well advanced planning would be crucial when dealing with a weather event.

21.5 Conclusion

To conclude, the process of selecting *Appropriate Technology* is crucial for all types of development initiatives and should be at the core of any intervention. Recognizing that appropriate technology goes far beyond of finding an engineering solution, that it is a ‘strategy enabling men and women to rise out of poverty and increase their economic situation by meeting their basic needs, through developing their own skills and capabilities while making use of their available resources in an environmentally sustainable manner' (Murphy et al. 2009), is a first step to ensure that technologies for sustainable development are more effectively appropriated.

The experience of HELVETAS Swiss Intercooperation emphasizes the importance of indigenous techniques and local knowledge and shows that they need to be at the heart when developing new technologies. Technology developed for communities should be well embedded into the local context, i.e. not be out of reach for the communities (need of external specialists, high investment, etc.). Similar results were found in other studies in the *haor* region, especially in the context of adaptation to climate change (Sawon and Khan 2011; Rahman et al. 2007). The Special Report on Extreme Events of the IPCC underlined that technological innovation may achieve resilience, especially when combined with capacity development anchored in local contexts.

Social acceptance among the stakeholders for new technology was particularly reached through the systematic involvement of local communities and authorities while at the same time skills building and knowledge sharing in the process of designing and selecting appropriate DRR measures have formed the bedrock of selecting appropriate technology. Last but not least, the experience also revealed that the understanding of the concept of DRR is a precondition that communities invest in risk reduction measures.

Considering the changing climate at the global level, it is clear that the discussion about appropriate technology will become an even more prominent and burning issue in future so that the involvement of local stakeholders and their local knowhow will be crucial. Climate change will challenge current technology in use and certain practices so that they may well become inappropriate due to the changing conditions. To conclude, it can be said that an appropriate technology is never appropriate per se, it is always dependent on the circumstances.

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Chapter 22
Academic Cooperation to Foster Research and Advocacy Competences in the Occupied Palestinian Territory (West Bank)

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Abstract Palestinians living in the West Bank, a territory occupied by the State of Israel according to International Law, face deprived access to land and a limited ability to move freely which pertains to the presence of Israeli settlements and other infrastructure (closures, restricted or forbidden roads, etc.). This confinement has significant impacts on their economic and social livelihoods, and it is even worsening with the on-going construction of a 709 km long Barrier which mainly runs inside the West Bank. With regard to this situation, there is a clear need to strengthen the capacity of civil society and its representatives to apply sound

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research processes as a basis for improved advocacy for Palestinian human rights. Monitoring processes and tools are needed to assess the impacts of the Palestinians' confinement, particularly in relation to the Barrier's construction. Reliable data has also to be collected, managed, and above all, shared. These challenges have been addressed within the Academic Cooperation Palestine Project (ACPP) that brings together academic partners from the occupied Palestinian territory (oPt) West Bank (WB), and Switzerland as well as other international academic institutions and Palestinian governmental and non-governmental agencies. ACPP started in early 2011 and is designed as a large cooperation networking platform involving researchers, students, public servants and experts from the oPt WB. A large set of actions have already been developed during the first year of the project, including courses, training, and research actions. First relevant results and impacts of the different actions are presented in this paper. Taken as a whole, the project produces valuable results for all partners: useful advocacy material for the Palestinian partners, and a unique "real-scale laboratory" where investigations are jointly conducted to develop novel confinement and change indicators.

22.1 Academic Cooperation Palestine Project and its Context

Palestinians living in the West Bank, a territory occupied by the State of Israel according to International Law, are deprived of access to land and have limited ability of movement pertaining to the presence of numerous Israeli settlements and other infrastructures (the Barrier, closures, restricted road networks, etc.). This confinement has significant impacts on livelihoods, and is aggravated by the ongoing construction of a 709 km long Barrier which runs to 85 % inside the Green Line and hence is located inside the West Bank, cutting off 9.8 % of the West Bank territory when fully constructed.

This situation has been documented regularly by organizations such as the United Nations Office for the Coordination of Humanitarian Affairs in the occupied Palestinian territory (OCHA-oPt) as well as the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) (see the most recent *Updated Barrier Report* (OCHA-oPt 2011). However, there is a lack of accumulation of methods to capture, store, analyze and publish such relevant information (what we call *research* in this context) by the Palestinian civil society. Therefore, there is a clear need to strengthen the capacity of civil society and its representatives to apply sound research processes as a basis for improved advocacy to defend Palestinian human rights. Monitoring mechanisms and tools are needed to assess the impacts of confinement on Palestinians, particularly in relation to the Barrier and its administrative regime. Reliable data has to be collected, managed, and above all, shared.

A gap analysis carried out by UNRWA's Barrier Monitoring Unit (BMU) has clearly shown that the West Bank needs to strengthen its research foundation for more effective advocacy in light of the occupation and the proceeding towards Statehood. Training of civil society and its representatives is a vital component of this endeavor.

There might be an ethical question related to the participation of foreign scientists to support and strengthen the position of one party in a conflict. However, as concisely stated by King and Kraemer (1993) in respect to the use of modeling tools in *policy warfare*: "To the extent that the GIS professional is "arming" the combatants, the arms are used in the fight against ignorance, confusion, and obfuscation. And the arms of modeling are successful only when all combatants have them". Thus, among many scientists working with one or the other party in this conflict, we may be fully comfortable in fostering knowledge and competences of the Palestinian civil society as the unequal occupied party and as mandated by international law.

These challenges have been addressed within the Academic Cooperation Palestine Project [ACPP] that was established by the BMU. ACPP serves a platform to bring together academic partners from the occupied Palestinian territory (oPt) West Bank (WB) and Switzerland, as well as Palestinian governmental, non-governmental and academic organizations:

- University of Birzeit
- Applied Research Institute Jerusalem [ARIJ]
- Ecole Polytechnique Fédérale de Lausanne [EPFL], with the Communauté d'études pour l'aménagement du territoire (Urban and Regional Planning Community) [CEAT] and the Research Laboratory for Geographic Information Systems [LASIG]
- University of Bern, Center for Development and Environment [CDE]
- The Palestinian Central Bureau of Statistics [PCBS]
- The Graduate Institute Geneva

This partnership started in early 2011 and is supported by UNRWA with funding from the Swiss Agency for Development and Cooperation [SDC] and EPFL. It is designed as a large cooperation and networking platform involving researchers, students, public servants and experts from the oPt-WB. The main objective of the first year was to prepare and submit projects to interested donors and funding agencies, to develop initial research projects, while contributing to education and training challenges.

22.2 Project Activities

The activities developed during the first year of the ACPP partnership are related to the development of research methods and processes on the one hand and to the development of training and academic courses on the other. This paper provides some insights into the most advanced of these activities.

Training courses were the most urgent and relevant activity to start with, fostering the creation of a network among participants and effectively supporting the development of *communities of practice* according to Wenger's well known concept (Wenger 1998). These communities may turn into the seeds for growing collaborative research projects and activities.

The following education and training-related activities have taken place since the initiation of ACPP:

- A training course (1-week module) in thematic cartography was organized through a "training of trainers" workshop at EPFL. It was consequently adapted to the Palestinian context by Palestinian instructors who since then taught five courses in Ramallah and Jerusalem to local researchers and policy-makers.
  As an example of good practice and successful learning, the map of the West Bank presented in Fig. 22.1 has been realized by the participants of the first course in Ramallah.
- A complete *Postgraduate Certificate in Research and Advocacy* course was designed under the lead of the Barrier Monitoring Unit and Birzeit University and discussed during an international workshop in Ramallah in May 2011 with different stakeholders. This postgraduate program is not only meant to train individual researchers and policy-makers, but also, by extension, aims at their organizations as a whole thereby empowering and building institutional capacity through knowledge sharing, conceptualized as a *learning community*.
- NGO Management five-day training course: This pilot project is to solidify the hypothesis that advocacy can be optimized through the application of quality research. It aims at humanitarian and development practitioners and their respective organizations. A by-product of this novel five-day course is to have its core ideas transferred to a Master's program in humanitarian action at the University of Geneva. This chain of events is testimony that a field-conceived academic initiative can have a South–North exchange of knowledge.
- A training workshop for GOs, NGOs and researchers in "Knowledge Management and Decision Support in Sustainable Land Management" was carried out as part of CDE's World Overview of Conservation Approaches and Technologies (WOCAT) program. Subsequently, a taskforce for the integration of the oPt into the global WOCAT network has been established by the Palestinian Ministry of Agriculture.
- Several research contributions were developed at PhD and Master level dealing with topics such as accessibility to health and education facilities, land cover change on both sides of the Barrier using remote sensing characterization of the West Bank territory by landscape metrics, and sustainable land management for improved agricultural production.
- An internship program with the BMU for Swiss students has been offered in collaboration with EPFL's association "*Ingénieurs du Monde*".

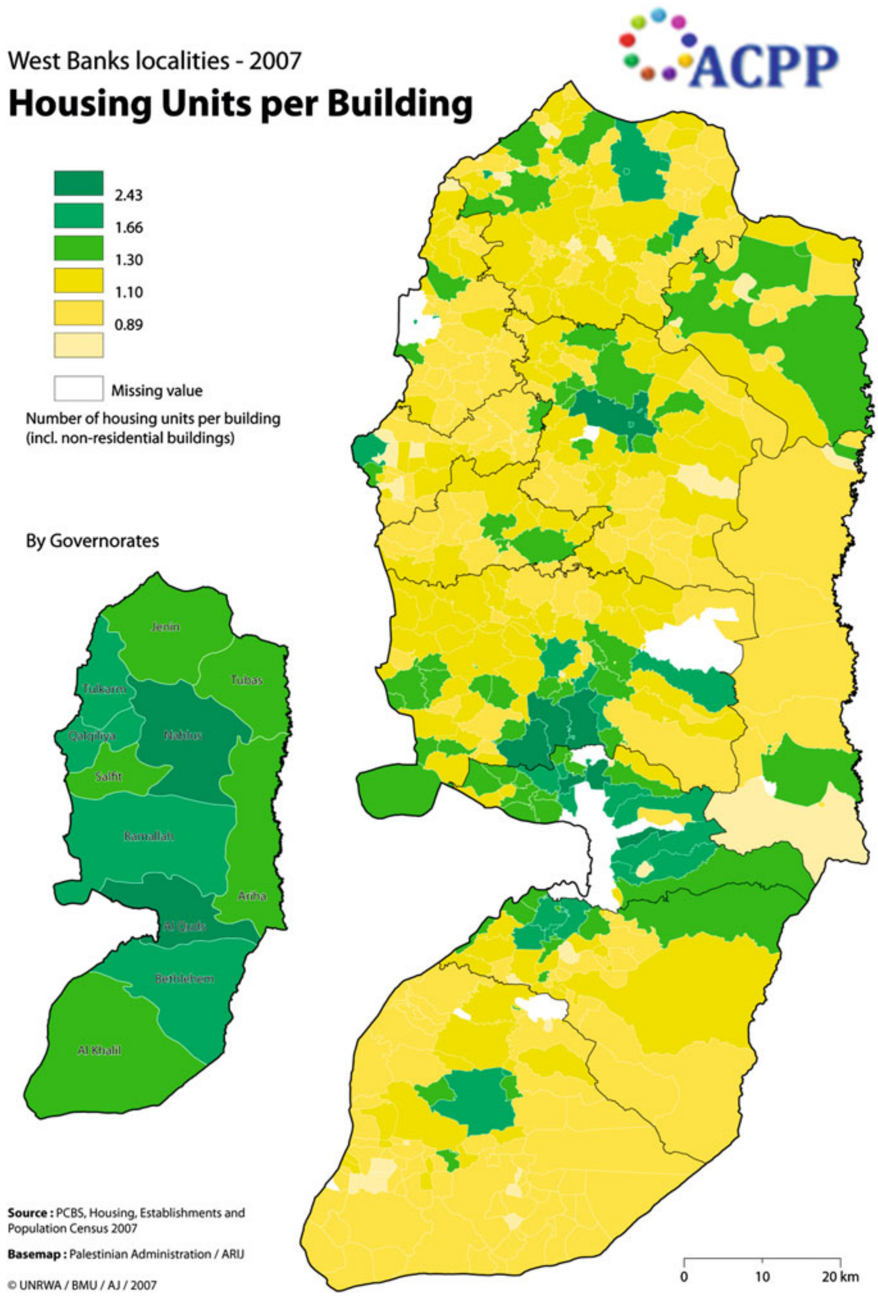

Fig. 22.1 Choropleth map representing the average number of housing units per building for the West Bank localities (Reprinted here with kind permission of BMU. *Data source* PCBS 2007)

22.3 First Results of the Project and Planned Developments

From many perspectives and exchanges with key Palestinian stakeholders, the availability of water resources, land use and land cover change under pressure of a growing population and closed markets, and accessibility to land and more generally to services are among the main strategic issues for the welfare of the West Bank.

Water is indeed a very critical resource in the whole Middle East, and several large research projects are already addressing it. Thus, the project will be more focused on the other strategic issues, i.e., land use and land cover change on the one hand, and accessibility to land and services on the other hand. The authors illustrate the former with a comparative study of land use and land cover change by remote sensing methods in the 'Seam Zone' (the area between the Barrier and the Green Line (1949 Armistice Line)) in the area of the village of Jayyus. The latter is illustrated by an accessibility study to health services under different gate closure scenarios elaborated by a team of Master students at EPFL with a strong local support from the BMU (data provision, contacts, etc.). Finally, the authors draw some perspectives on a larger research project they are developing on land use change under pressure.

22.3.1 Study on Local Land Use/Land Cover Change by Remote Sensing

UNOCHA-oPt has been monitoring and reporting on the humanitarian impact of the Barrier on Palestinians since April 2003. Along with general statistics on the West Bank land and Palestinian population affected by the construction of the Barrier, UNOCHA-oPt reports provide, mainly through case studies, analysis of Palestinian's narrowing access to the land located between the Barrier and the Green line and its social and economic consequences (for more see: www.ocha-opt.org). In a report published in 2008, this United Nations office estimates in particular, that the Barrier and its associated measures have "severely limited the access of Palestinian farmers to their land in the Northern West Bank" (UNOCHA-oPt 2008, p. 4). The Barrier in this part of the West Bank is completed and the land located west of this Israeli infrastructure and the Green line was declared closed by military order to Palestinians in October 2003 and a permit and gate regime instituted. Consequently, Palestinian farmers living east of the Barrier and willing to cultivate land located west of this Israeli infrastructure face difficulties in their freedom of movement and their capacity to produce: permits denied on the grounds of "unproven" connections to land or for security reasons, short validity period for permits granted, limited gate opening hours, etc. As stated in the 2008 UNOCHA-oPt Barrier report, this situation has therefore created "a reduced opportunity for cultivation" which "has led to the dismantling of the greenhouses and a change to lower-maintenance and lower-yield crops" (Op.cit.).

However, these statements rely on field observations only and to date, no comprehensive figures and/or cartographic representations exist to support them. By using multi-temporal and panchromatic or multi-spectral high-resolution satellite imagery (CORONA–QuickBird–SPOT5) and by developing a set of computer-driven detection procedures in addition to visual interpretations, the two partner laboratories at EPFL (CEAT and LASIG) are conducting an analysis for UNOCHA-oPt which is an attempt to characterize (typology mapping) and quantify the above mentioned changes. This survey is entirely funded by SDC and is focusing on the Jayyus area (Fig. 22.2) where the West Bank Barrier's impact

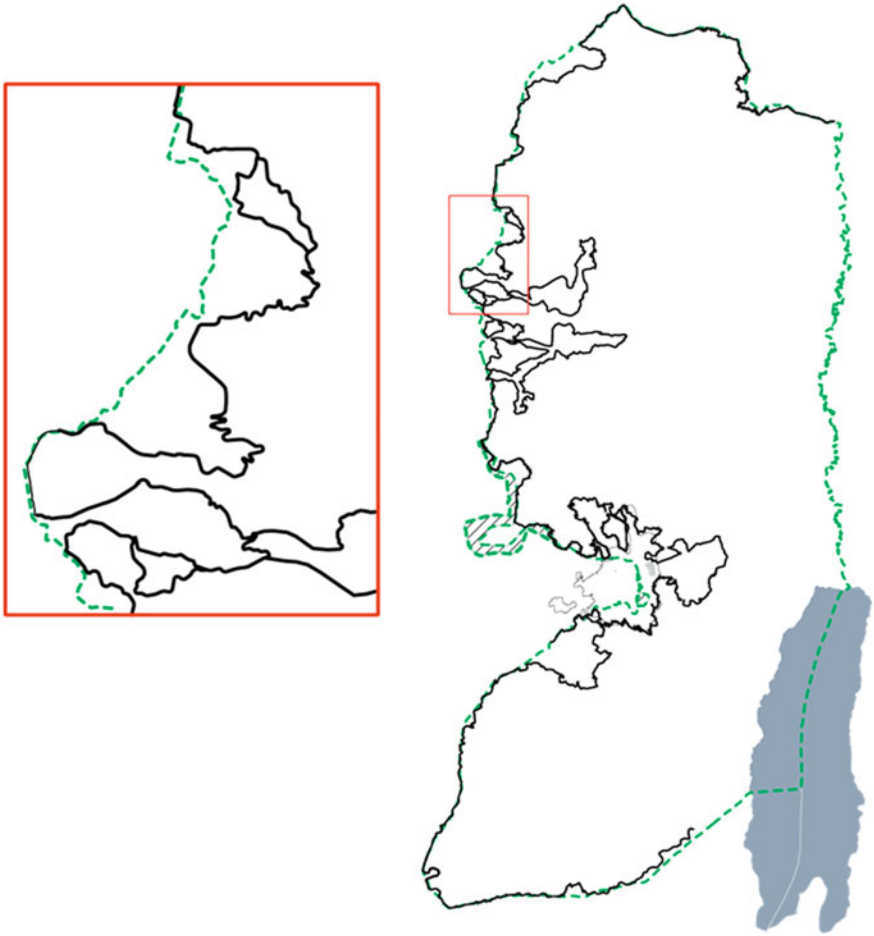

Fig. 22.2 Area of focus of the land use/land cover study (Reprinted here with kind permission of BMU. *Data source*: OCHA oPt 2012)

on land cultivated by Palestinian is estimated to be significant by UNOCHA-oPt. Once this analysis is completed, 3 maps displaying 5–9 Land-Use/Land Cover (LULC) classes such as ‘urban fabrics’, ‘greenhouses’, ‘cultivated land’, will be provided to UNOCHA-oPt along with statistics estimating the surface area for each LULC classes and disaggregated per relevant sub-areas: east/west of the Barrier, enclaves, etc. The two first maps will show the human use of land and the physical material at the surface of the earth in the Jayyus area as of 8 March 2003 and 4 April 2010 respectively. The first date corresponds to the beginning of Barrier construction and before the Israeli military declared the zone west of the Barrier a military closed area, while the latter corresponds to a time seven years into the construction and the Barrier around Jayyus had been fully constructed and the military order put in place. For a broader historical overview, the third map will show the LULC of the Jayyus area as of 8 June 1970, i.e., three years after the beginning of the occupation of the West Bank.

22.3.2 Accessibility Study to Health Services Under Different Gate Closure Scenarios

The first year of the ACPP project offered also a very appealing framework to associate some groups of Swiss Master students to the investigation of the research questions. A number of students were interested in the analysis of accessibility scenarios to central services (as for example health services) under different constraints (in our case, under diverse gate closure scenarios). Two scenarios are represented on Fig. 22.3: a direct route between Jerusalem and Ramallah through

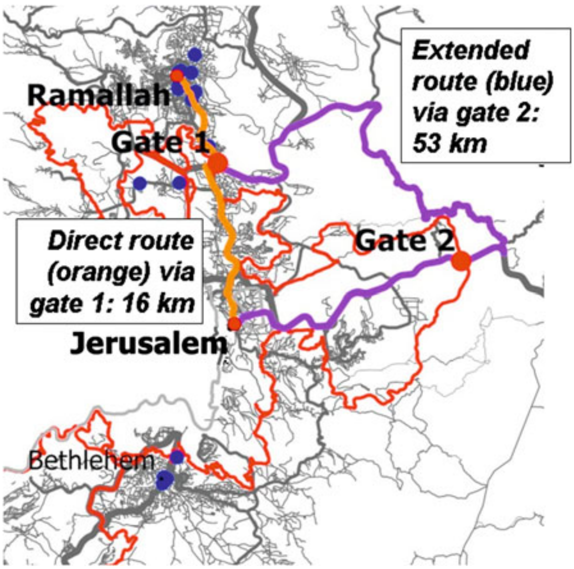

Fig. 22.3 Two accessibility scenarios used for the development of the accessibility analysis method. (Reprinted here with kind permission of EPFL-LASIG, C. Vautey)

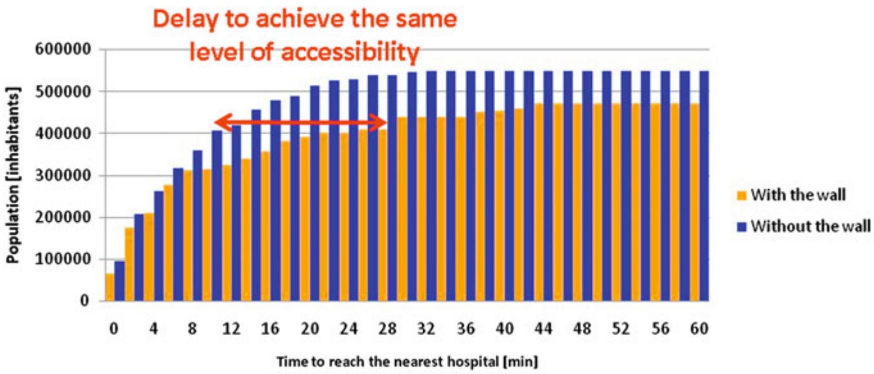

Fig. 22.4 Comparison graph of accessibility in function of acceptable travel times for different scenarios

gate 1, and an alternative (longer) route through gate 2 in case of the gate 1 closure. It is important to note that the two considered scenarios have been elaborated to support the development of the method, and have not yet been validated in reference to the actual conditions (actual demand for health services and their actual location, actual gate closure regimes and uncertainties, driving speeds and traffic jams, behavior of the patients in need to reach a hospital, etc.). Therefore, the obtained accessibility figures cannot yet be considered for advocacy.

Standard spatial analysis algorithms have been used to systematically compute the travel time from any location in the central part of the West Bank and Jerusalem to any health service identified in the same area. However, a very novel approach of accessibility has been used, that was developed in a recent thesis at EPFL (CEAT) (Dessemontet 2011). The accessibility is not expressed in hours and minutes of travel time, but in the number of persons that have access to the service according to a maximum acceptable travel time. In Dessemontet's original study, the maximum acceptable travel time is statistically derived from large amounts of observed data. This is not possible, nor relevant when considering the accessibility to health services: who would give up in need of a hospital? Thus, the students suggested to study the accessibility for a continuous series of maximum travel times, presenting a graph with two scenarios to compare, as suggested on Fig. 22.4. The graph shows how many people have access to given sets of services in function of a chosen acceptable travel time. But the graph can also be read from the population scale, and may give information of how much additional time has to be accepted to give the same level of service to the same population under a more constraining scenario.

22.4 Incorporating Lessons Learnt: ACPP's Way Forward

To integrate the learning within ACPP's platform of partners is an experiment all of them are willing to pursue. The 2nd international workshop held in Ramallah culminated in the concerted effort to produce a multi-layered project for a pilot phase of three years. It was agreed that all aforementioned activities and outputs of the ACPP to date are to serve as the springboard to launch a thematic project based on land use models exposed to a variety of human made shocks. Within this vast field it is deemed academics and practitioners will find ample opportunity to create synergies with clearly defined common goals.

The natural progression of ACPP activities within the framework of partnership networks is currently being proposed through concept papers and the elaboration of a project proposal following a North–South collaboration principle with firm ownership in the South.

22.4.1 Establishment of a 3-Year Research Project: Land Use and Management in the West Bank: Coping with Shock Conditions

During the last 60 years, a series of shocks affected almost all aspects of planning and management of resources indeed all aspects of daily life in the West Bank. These shocks include wars (the 1948 and 1967 wars), population displacements (the 1948 Palestinian exodus), and the ongoing Israeli occupation and its related policies, resulting in extensive pressure on existing resources and a total fragmentation of the remaining Palestinian lands through the division into areas A, B and C. A more recent shock occurred due to the construction of the West Bank Barrier (of which 61.8 % is constructed, 8.2 % under construction and 30 % planned) and its related permit and gate regime. These pose restrictions on movement and access, limiting access to agricultural lands, services and markets while currently isolating around 6,500 Palestinians in closed military areas between the Green Line and the Barrier, referred to as the Seam Zone (OCHA-oPt 2011).

If we are to understand and investigate past evolution and future foreseeable trends in resource management and planning these shocks play an essential role in addition to the usual drivers for change such as demography or climate change. Changes in land use are to a large extent the result of the complex and intricate impacts of these combined shocks. Land management, however (and especially sustainable land management in rural areas) can serve as a possible way to mitigate these impacts and furthermore offer solution oriented approaches to cope with the current situation, to monitor trends and deal with crucial issues such as food security and water resource management.

In order to address past, current and future trends in land use and to mitigate against resulting impacts high quality research is required. Furthermore, it is necessary to raise awareness and build local capacity to advocate against these impacts by using research data and outputs.

Within the Palestinian research community, GOs and NGOs major gaps regarding the use of data for efficient advocacy are:

1. Lack of a global, integrated, common understanding of using data for advocacy;
2. Limited access to information and scattered data;
3. Lack of capacity in data collection, processing and analysis and the provision of facts for advocacy and decision-support, thereby creating a direct relationship between research projects and advocacy outputs.

The proposed project is assessing and monitoring the impacts of shocks through the creation of a so-called learning alliance, a multi-stakeholder platform that facilitates action research and capacity building. The learning alliance will serve as a model for interdisciplinary research whose aim is the application of research data for improved advocacy.

The project will be based on the following three elements:

- Setup of a **learning alliance** to progress towards a shared common global understanding, improved access to information and knowledge, and the development of more effective advocacy strategies. The learning alliance will bring together a broad range of interested stakeholders, including the Palestinian administration, UN-related bodies, NGOs, local research institutions, the Swiss partner research institutions, and the main ACPP partners Birzeit University, BMU, ARIJ and PCBS acting as facilitators. The detailed objectives and activities of the learning alliance are in the process of being defined on the basis of a multilateral agreement.
- **Research** aiming at establishing a new knowledge base which is relevant in view of improved advocacy in regard to impacts of shocks. Evidently, these impacts as well as the various interests that will be generated in the learning alliance cover a wide range of concerns. Land use and sustainable land management provide an overarching framework to address a multitude of specific issues (some of them undoubtedly object of ongoing research) and bundle them together in a global picture. In addressing issues related to the management of resources, along with their socio–economic and spatial pattern dimensions, this research will advantageously build upon the complementary skills and expertise of the three involved Swiss research institutions and their international counterparts. Furthermore, the research part offers a framework to directly involve Palestinian research institutions, build capacities through joint research and to develop sustainable partnerships.
- As stated previously, there is a lack of experience and know-how regarding the use of raw data and information to produce the facts and evidence needed for advocacy. Capacity building through the establishment of a **postgraduate training program** will form an integral part of the learning alliance's activities. It is closely connected to research and therefore constitutes the third major corner stone of this proposal.

22.5 Conclusive Remarks

The outcome of the January 2012 workshop among most of the ACPP partners present is a solid commitment from multi-disciplinary research institutions both academic and applied to work together in order to strengthen advocacy with the help of good research practices. ACPP is now consolidating all efforts to express the common goals stated above and elaborated over the last one and a half years to find funding mechanisms to make its vision a reality.

Taken as a whole, the project produces valuable results for all partners: useful advocacy material for the Palestinian partners, and a unique "real-scale laboratory" where investigations are jointly conducted to develop novel confinement and change indicators.

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Chapter 23
Fog Collection Technology Transfer and Co-Creation Projects in Falda Verde, Chile and Tojquia, Guatemala

Fernanda Rojas, Virginia Carter and Melissa Rosato

Abstract There are numerous development projects around the world that seek to provide technological solutions, however these technologies do not prosper because technology transfer, and especially co-creation, is often neglected. The NGO FogQuest has tried to center these themes into fog collection initiatives which are both technological and social endeavors. The technology used are Large Fog Collectors (LFCs) which are composed of vertical panels of mesh (typically 40 m^2) with an under hanging gutter erected using posts. LFCs collect water from fog and rain on its surface making it a physically viable water supply for certain rural communities with few alternatives. The technology is simple enough that it can be locally operated and managed, making it appealing from a social or management perspective. Because projects around the world face the challenges of integrating geographic suitability and local capacity, attempts at technology transfer that focus explicitly on the empowerment qualities of the technology can be an indicator for long-standing success. Through two case studies, this paper evaluates different project approaches in decisions surrounding the introduction and implementation of fog collection technology exploring both the physical and social needs in a technological intervention. The evolution of technological fog collection knowledge was examined with a focus on adaptability in the context of community idiosyncrasies where it is developed. It was determined that technology transfer and co-creation are inherently linked and need to be pursued in the right context and with the appropriate processes.The implementation of innovative technologies for sustainable development is achieved only with a strong dedication towards the learning and empowerment of the benefited communities.

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23.1 Introduction

There are different ways any development project can be initiated and pursued and diverse project goals influence technology learning, empowerment, community motivation and management. Fog collection projects face the dual challenge of integrating scientific and social considerations, in particular geographic or climatic suitability and local capacity to implement and manage community systems. Fog collection in modern times began in Chile in the 1960s, though there are fog collection initiatives in at least 18 countries (Klemm et al. 2011). Large Fog Collectors (LFCs) are vertical panels of mesh (typically 40 m^2 each) with under hanging gutters erected using posts. LFCs collect water from fog and rain on the mesh surface making it a viable water supply for certain rural communities likely with low population densities and few available alternatives. LFC materials are sourced locally facilitating the access of replacement parts. It is a viable water supply system for rural communities, especially in arid or semi-arid regions with few options. This paper evaluates how different origins, project goals and implementation practices have influenced technology learning, empowerment, community motivation and ongoing management in fog collection projects.

23.2 Design and Methods

This paper uses case-study methodology to compare two successful fog collection projects designed and implemented by the Canadian NGO FogQuest in Falda Verde, Chile and Tojquia, Guatemala. In particular, different project approaches in decisions surrounding the introduction and implementation of fog collection technology were analyzed. Applied technology transfer project challenges are contextualized within case specifics to evaluate lessons learned and elaborate best practices. For both cases, three project stages were considered: (1) how the technology viability was assessed and initially implemented considering geographical and social factors; (2) how the technology was adopted by the users taking into account sustainable operation and maintenance; and (3) how the prior processes have influenced the future goals for both projects.

23.3 Results

The following discussion demonstrates that, despite the standard nature of fog collection technology per se, the way it is implemented is by necessity unique in each community. Fog collection technology is a viable and effective solution to water shortages, but it is the way the implementation process is undertaken that dictates ongoing, sustainable success from a management perspective.

The Falda Verde project, with 400 m^2 of collection surface produces an average of 600 L of water per day and is helping sustain a fisherman's association in growing 1000 Aloe Vera plants in the driest place on earth: The Atacama Desert. The Tojquia project, in Guatemala uses a decentralized household-level framework which includes 35 LFCs and 1400 m^2 of collection surface. It is currently the largest community-built and run fog collection project in the world producing an average of 6000 L of clean water per day and helping over 150 individuals. Given the project goals of empowerment, some of the beneficiaries are now capable of building LFCs without external supervision and are effectively managing the project via existing community structures. The cases suggest that technology transfer and knowledge co-creation are inherently linked and are dependent on context. The empowerment of a community or group can lead to motivation and co-creation of knowledge. When the origins of a project are through technology transfer, it should evolve into a co-creation participatory process for ongoing success.

23.3.1 Assessing Technology Viability: Physical and Social Factors

23.3.1.1 Physical Factors

Both the Chilean and Guatemalan projects have the required factors that determine fog collection suitability (Schemenauer et al. 2005). Falda Verde is located in the III Region of Chile, as per the map below, in what is called the "door of the Atacama desert" due to its aridity and biodiversity. Typical sources of water are extremely limited. However, both advection and orographic fogs (as a result of the combination of subsidence generated by a permanent high-pressure area over the Pacific Ocean and the atmospheric stability induced by the cold northward-flowing Humboldt Current) are consistently present, signaling an important and useful source of water (Larraín et al. 2002). Fog collection potential was formally evaluated using the Standard Fog Collector (SFC) and expresses how many liters of water per square meter of mesh is produced in one day (L/m^2/day) (Schemenauer and Cereceda 1994). Falda Verde fog water measurements have produced an average of 1.46 L/m^2/day (Carter et al. 2007) (Figs. 23.1 and 23.2).

The village of Tojquia is located in the Western highlands, in the department of Huehuetenango, Guatemala and sits atop the Cuchumatanes mountain plateau facing the Tojquia valley (Fig. 23.3). This area's altitude ranges between 3300 and 3460 m above sea level and experiences strong winds and temperatures that drop below 0 °C during the dry season months of November to April. Fog collection rates here average 4.5 L/m^2/day (data collected by the authors) during the dry season. By contrast, the rainy season sees a three to four-fold increase in rain rates often resulting from heavy thunderstorms and extreme weather such as hurricanes (Schemenauer et al. 2007).

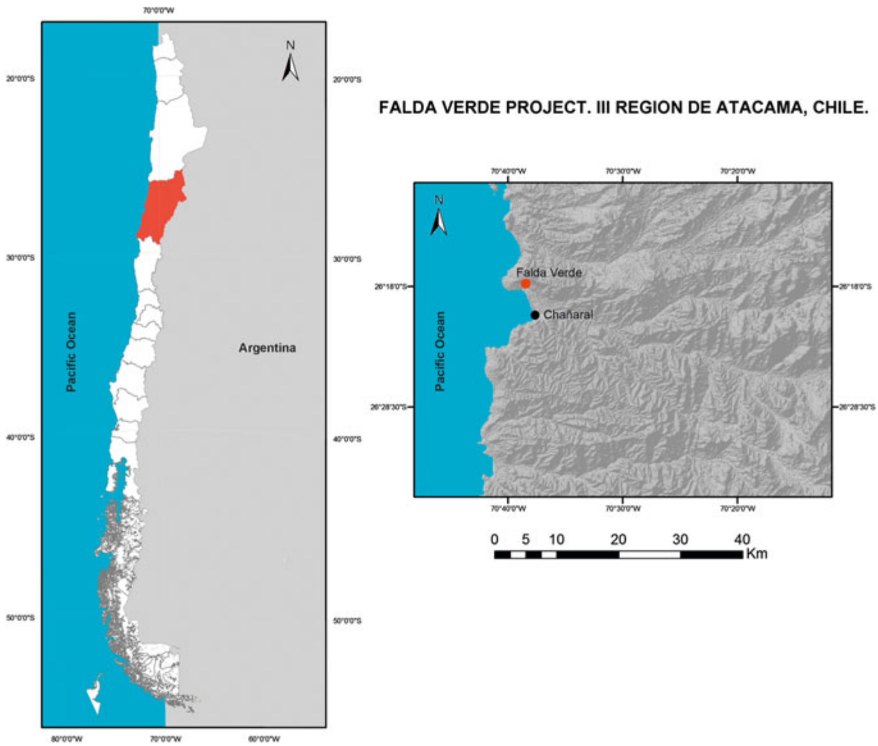

Fig. 23.1 Map, Falda Verde project, Atacama region, Chile

Fig. 23.2 LFCs, constructed between 2001 and 2005 on Falda Verde Mountain (Reprinted here with the kind permission of Carter et al. 2007)

Besides the presence of fog, the lack of water options in both places is the other necessary condition for the implementation of this technology. In both Falda Verde and in Tojquia there are no natural sources of water (rivers, groundwater) or

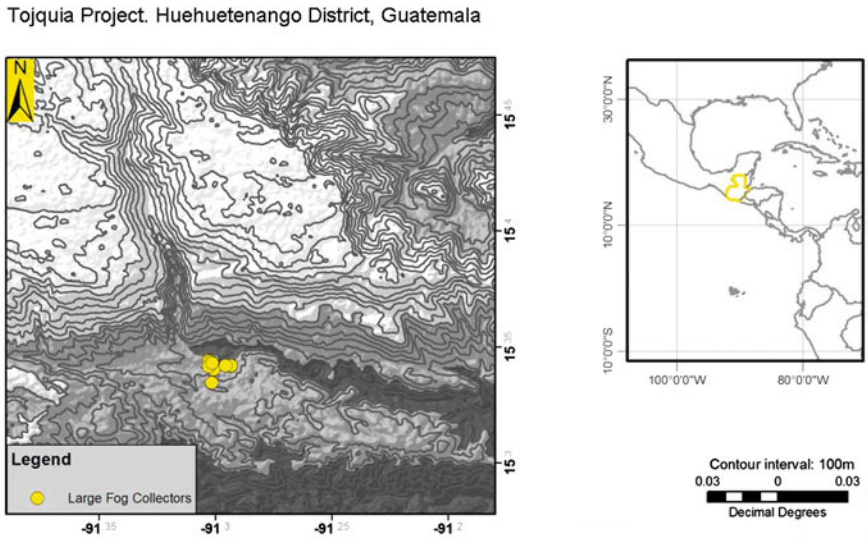

Fig. 23.3 Map, Tojquia project area (Reprinted here with the kind permission of Rosato et al. 2010)

wells. In Falda Verde potable water is sold by truck. The people from Tojquia and the nearby villages rely only on watering holes located at the valley bottoms which require upwards of an hour-long walk. Here they wash their clothes and carry back up to the village as much water as they can manage for their water needs. This is an arduous task most often undertaken by women and children.

23.3.1.2 Social Factors

The Origins of the Projects The two highlighted projects have contrasting origins. The Falda Verde initiative began in 2001 when the "Atacama Atrapanieblas Group", (a local fishermen association), recognized the fog water potential from the emblematic fog collection project "El Tofo, Chungungo" and petitioned support from the local government (Carter et al. 2007). In 2001, six LFCs and accompanying infrastructure such as pipes and holding tanks were built. FogQuest facilitated with additional funding and support for another four LFCs in 2005. In all ten LFCs with a total collection surface of 400 m^2 were erected in Falda Verde. These collectors continue to produce an average of 600 L of water per day in the Atacama Desert, the driest place on earth.

In 2006, FogQuest volunteers traveling through Tojquia observed a single LFC erected on the mountainside and stopped to talk to the owner. Without the backing of any formal support, local accounts state a lone individual provided a screen mesh and suggested this be used to make use of the frequent fog. The elderly man in Tojquia who was approached did this successfully for several years leading up to the initial encounter with the NGO. FogQuest staff also concluded initial geographic suitability given the observed fog, “foggy zone” highway signs, as well as obvious water needs at 3300 m elevation. A more detailed water needs assessment initiated the work in Tojquia although with minimal community participation. Tojquia remained a community still distrustful of outsiders, sentiments from the effects of a long civil war which ended in 1996. Broken political promises common among marginalized rural communities in developing countries highlighted the need to build up trust as a precursor to a project (Rosato et al. 2010). After an initial LFC build session, the community saw that FogQuest was committed and had available resources. They proactively approached FogQuest members to expand the efforts and continue to introduce the technology and evaluate suitability collaboratively. In seeking work at the community level, FogQuest inquired about formal associations under Guatemalan law and was informed the locally-led Mam Ma QosquixAssociation was organized and already working on development issues in Tojquia.

In both cases, the existence of an association is fundamental as it legitimizes the commitment and willingness of participatory community work together with external actors, in this case the NGO FogQuest. This collaborative element should be present in every development project for several reasons. First, because it emphasizes the need to come together to pursue joint goals that affect many households in a community, as is often the case with water-limited communities. Secondly, it can help limit unhealthy cycles of dependency for which development can be criticized, including the notion that help must be brought in from the outside. Empowerment is fostered from the fact that a community association is encouraged to participate and be accountable, to share ideas and contribute to a project from its inception. This local participation, however must include decision-making and goal development, it should not only be limited to implementation. It is here where discussions with the association regarding project implementation need to occur.

Manual Labor as a Key Component In FogQuest’s experience, during the building stage of LFCs, significant contribution of manual labor is required and has been undertaken with complete association support. Men and women contribute to digging anchors, preparing cables, lifting and tensing the structure, sewing the mesh, installing the gutters, and all the other technical tasks that are needed. Often referred to as the “sweat equity” of a project, in the case of LFCs, this manual labor is chosen not for the primarily purpose of lowering project costs or fostering ownership by virtue of time commitment, it is a fundamental opportunity for the association members to teach and learn all about the technology in an experiential setting. Most importantly, locals are able to teach each other important skills too. This villager-to-villager exchange further highlights the importance of working through an association with established protocols for collaboration. It is in this way that locals can become agents of change. When a community fog collection project is pursued and the intention is technology transfer, the LFCs should be built entirely by the local community. It is the artisanal nature of LFCs and the process of construction that enables the technology to penetrate into the participating community from the onset of a project.

Fostering Capacity through Local Management Structures The Falda Verde initiative is managed by a group of fisherman who live in Chañaral, a small town with livelihoods based on mining, fishing and port activities. Over the past 20 years, the percentage of the population that is rural and not urban in Chañaral has decreased significantly, though the most recent census indicates this trend may be changing (Instituto Nacional de Estadística de Chile 2012). The process of urbanization can affect people's expectations regarding their quality of lives and can help foster entrepreneurial ideals. That the Chañaral region enjoys a high literacy rate of 96 % is also a benefit to social processes (Plan de Desarrollo Comunal para la comuna de Chañaral 2008). The group of fishermen planned the Falda Verde project looking for an alternative to their customary sporadic and physically-demanding work. Pursuing change proactively is the context under which the fishermen sought technologic innovation to improve their lives. One could say this group was empowered from the beginning with the project.

In Tojquia, local capacity has been promoted in different ways. FogQuest strives for experiential learning which is more amenable to local populations with low levels of formal education. However, here there is the added challenge of communication between NGO staff and locals since some villagers speak only indigenous Mam, one of 23 different Mayan languages in Guatemala. The Association Mam Ma Qosquix plays an important role by tracking manual labor participation and uses lists of past attendees on LFC builds to help determine future LFC beneficiaries. Even indirect contributions such as helping to host a group of visitors, providing storage space for materials, cutting firewood for guests, etc. are all tasks that are considered participation for the project. In a small way this recognizes the efforts of women and is a step towards addressing gender disparities. Exceptional cases regarding widows or families at a disadvantage are given special consideration for benefits by the association and are not excluded as is the policy FogQuest promotes. In early 2012, FogQuest produced and shared a visual maintenance and operation LFC guide to facilitate local learning. Sharing ideas and innovation is highly encouraged. On one occasion when more sewing needles for the mesh were needed but could not be immediately sourced, one individual fashioned new ones out of bits of rigid plastic, a task he had never done. More significantly, the 35th LFC was built under complete village leadership and oversight and was left fully operational.

Overall in Tojquia, most decisions are made by consensus in an open dialog environment the association has fostered. These practices have worked very well for the technology transfer of fog collection as it allows the FogQuest volunteers to maintain political neutrality to a large extent. The notion that the locals can participate with good ideas and suggest changes to initial plans is encouraged and in turn, local leaders are empowered in managing important project decisions. It should be highlighted that this method is facilitated by an ongoing commitment made by the project volunteers to return when possible to continue to expand the initiative together and help assess ideas as they are produced.

Trust is also an important element that encourages ongoing motivation to participate (Rosato et al. 2010). When this trust is broken, as can be the case with corrupt local managers, a project is at risk. In Tojquia, one of the initial leaders was charging an exclusionary fee to participants and the association's membership responded by demanding more inclusiveness and respect, and elected more trustful representatives. Leading the local water committee is a task shared by two village men currently and the growing list of interested participants is an indication they garner the required skills for this task. This resilience in local management capacity demonstrates empowerment by the villagers to take charge of matters and respond to problems, technological or social, as they arise. This particular community management issue reflects what Klemm et al. (2011) identify as the most difficult when implementing fog collection technology: ongoing management and operational aspects, discussed as follows.

23.3.2 Technology Adoption: Sustainable Operation and Maintenance

In Falda Verde Technology adoption was immediate in the Falda Verde initiative since pursuing fog collection was at the request of the local community group and is thus linked to the project‘s origin. The fisherman's association had proactively set aside land and had clearly elaborated ideas regarding the future use of the fog water. There are currently seven functional LFCs producing fog water in the desert and growing Aloe Vera for the involved members. It could be said that this initiative truly did result in co-creation of this technological application from the onset. However, the association has not yet achieved the success it had initially sought which was to produce a new economic livelihood from this source of water. The locals cite challenges in raising necessary capital funds in order to pursue expansion. Part of the work that remains in Falda Verde includes having FogQuest promote this existing project and finding interested donors to pursue the goals of ongoing maintenance, operation and expansion.

In Tojquia The operational phase came with the very gradual implementation of a decentralized, house-by-house framework for LFCs that initially emphasized technology transfer during the construction phase. With each annual build session, the association self-selected new leaders for the construction phases. These were not always the most technically-adept men, but they were often good communicators since they were responsible for learning the technology and helping diffuse the concepts to the rest of the participants. These construction leaders co-created building knowledge by adapting their teaching and communication to incorporate cultural and language considerations to their local context.

When a leader or other participant would not be able to assist in a build or meeting in Tojquia, the responsibility for an ongoing presence was demonstrated by having other family members attend in their place. Despite a less efficient work pace, there were many advantages that emerged. The involvement of new individuals opened up the possibilities for different ideas and even resulted in new leadership figures to emerge to fill voids. This slower technology transfer also improved local-to-local teaching techniques and thus facilitates co-creation and empowermentin more organic and substantive ways. The slower pace placed greater pressure on the participants to achieve the build goals during a specified timeframe, and this in turn highlighted the need for full participation. Contrasting this slower method with a single construction timeframe without an emphasis on the capacity development of the beneficiaries and users, the adoption of the technology would result ineffective since the needed skills for ongoing operation and maintenance are not built up. The process of building an LFC raises an important awareness of the requirements for its ongoing care and fosters ownership of the technology. For this reason, the number of LFCs constructed can be less important than the manner in which they were built. A greater measure of successful technology transfer is not how many LFCs are built but how many remain functional after a specified amount of time without external involvement. For this reason, an emphasis on measuring how capacity is developed is suggested in lieu of an emphasis on a technology's hardware as an indicator of success.

Empowerment and Project Sustainability While knowledge of the technology is required for ongoing operation and maintenance; it is the individuals in village-level management structures that require a combination of the technical skills but also the social skills to ensure sustainability of these systems. Empowerment is a critical component which can be fostered by gaining familiarity with the technology and then suggesting ways in which it can be adapted to better suit local needs. In one example, given the requirement to maintain the gutters clean, free of debris and properly attached to the bottom of the mesh, the LFC owners found the suggested height of 2 m to be a barrier to proper maintenance. An evaluation of the tradeoffs of LFC height were discussed together. A collector with a height of 2 m does more easily permit the movement of livestock underneath it; this height can limit the vectors for contamination; it can also increase the fog water collection rate. However, a height of 2 m impedes accessibility, especially given the short stature of most individuals in the Guatemalan highlands. This accessibility issue trumped the others. The request to lower the height was made possible by individuals who felt their position on suggesting a technological change would be heard, respected and considered for implementation. As the project progressed, several collectors initially built at this height would be modified to incorporate this suggested change. More than a mere technological suggestion, the voicing of this idea and the subsequent implementation is demonstrative of a collaborative process that strives for empowerment via local participation. In the end, both local users of fog collectors and FogQuest members have the same goals of sustainable water production (Fig. 23.4).

Fig. 23.4 Construction by local Tojquian villagers, 2010

23.3.3 Rethinking of Goals and Project Evolution

In both projects, what started as initiatives to simply provide rural communities with a new water source via fog collection have evolved to include more complex objectives. In Falda Verde, fog water is producing economic benefits by way of helping grow 1000 *Aloe Vera* plants for local markets. This approach represents a case where empowered stakeholders sought to co-create knowledge and implement solutions that would change their lives. At 35 LFCs and 1400 m^2 of collection surface, Tojquia is currently the largest community-built and community-run fog collection project in the world producing an average of 6000 L of clean water per day and helping over 150 individuals. While the provision of a new water source was initially the desired feat, the way in which this was achieved is equally relevant. That some of the beneficiaries are now capable of locating and building LFCs without FogQuest supervision is an aim that was not anticipated but is now a greater focus. The objectives of this initiative have evolved to include local maintenance, operation and management of the new fog collection systems. The idea is that the leaders in the community with technical skills will be the subsequent agents to transfer this technology to neighboring communities seeking their knowledge and support.

23.4 Conclusions

When a community by its own initiative seeks support from an organization, as in the Falda Verde case, the existing motivation can be satisfied by immediate technology transfer. However, an approach that does not heavily emphasize co-creating a technology may not include the same level of awareness-raising regarding the needs of that technology and may result in failures in maintenance and operation, and even deficient management structures. In this event, the NGO's knowledge may be effective for the stated goal of technology transfer but it may not be able to intervene beyond what was initially proposed. This limited engagement is not necessarily negative but does result in less adaptive and transformative initiatives. The contrasting goals of leaving functional technology intact, which an NGO might desire, is most likely at odds with the ideals of the beneficiaries which often seek more ambitious projects to be pursued in future years and requires social factors be fundamentally addressed. This case suggests co-creation of the technology by the actors involved should be sought for improved sustainability.

The initial empowerment via technology transfer in Tojquia has led the association to consider broader objectives. The local participants claim they no longer suffer water shortages during the dry season or have to walk long distances to fetch clean water for their most basic necessities. However, they are also realizing that while it is an important assistance, it is not enough. Community members now seek expansion, not only in terms of personal water production and storage, but are thinking in terms of economic motivations. In Tojquia, leaders are already imagining a context where they are multipliers of this technology in their neighboring villages offering a knowledge and skill set for which they might be in a position to charge a basic fee. Given the already documented interest and requests for assistance, this new goal may not be far-fetched. Local-to-local technology transfer and co-creation in terms of fog collection technology represents an exciting alternative to traditional North–South or "expert"-to-local development models, of which few rural communities in the developing world have been able to experience firsthand.

The cases presented suggest that technology transfer and co-creation are inherently linked. One is not better than the other but they need to be pursued in the right context and with the appropriate processes. The empowerment of a community or group can lead to motivation and eventually the co-creation of knowledge within projects. This co-creation is a necessity for truly collaborative work. When the origins of a project are through technology transfer, it will ideally evolve into a co-creation participative approach to achieve sustainability. Empowerment of local agents of change comes from local understanding of a technology but also by instituting processes and environments that will ensure new ideas can be considered and debated openly. This in turn will contribute to motivation and ongoing success and have important implications for leveraging the impacts of technology for development worldwide.

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Chapter 24
Role of Village Resource Centers in Technology Diffusion and Development

C. S. Shaijumon and Satheesh Menon

Abstract The Indian Space Research Organization (ISRO), with the objective of disseminating knowledge to the rural masses, envisaged the Village Resource Centre (VRC) concept in 2004. VRCs conduct interactive programs on a regular basis and are connected to knowledge producing institutions. This study empirically analyzes the impact of VRCs in agriculture by capturing productivity levels and innovation performances. Results show that the impact of new developmental interventions through VRCs is significant in knowledge diffusion, innovativeness, and productivity of farming communities and, it can be quantitatively measured. VRCs help improve the quality of life in villages by providing new knowledge at the doorstep of the common man, in vernacular language, thereby reducing information inequality and the emergence of a new socio-economic relationship.

24.1 Introduction

Space Technology and Information Communication Technologies are state of the art technologies of modern civilization. However, the potential benefits of these technologies can only be realized when they are successfully diffused to a large number of end-users. In developing countries, the benefits that technology brings are normally accessed only by a rich minority, with relatively high absorptive capacity. Yet, the ultimate way to measure the benefits a new technology can

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contribute to economic development, is only when it is successfully transferred and correctly applied by a large number of the intended end-users. The Indian Space Research Organization (ISRO), with the intention of disseminating knowledge to the rural masses by using the advancement of Information Communication Technology (ICT) in space research, has envisaged the Village Resource Centre (VRC) concept. ISRO's VRCs programs are carried out in association with NGOs/Trusts and state/central Government agencies, and are connected to knowledge producing institutions including universities, government research institutes, hospitals, and others. The primary objective of the VRCs and their corresponding networks is the introduction of interactive programs in areas such as agriculture, water resources, tele-health care, awareness programs, skills development and vocational training for livelihood support. In India, more than 500 VRCs have been established in 22 States and Union Territories; and the Eleventh Five Year plan (Government of India 2008) has recommended the creation of 10,000 new VRCs. The uniqueness of VRCs is the knowledge connectivity between experts at universities and research and development (R&D) institutions with the village communities. An important actor in the concept of VRC is, for example, an agricultural university, for which space technology serves as a platform for linkage and dissemination of knowledge of their research to the local community. Accordingly, VRCs support universities in discharging their third role, i.e., (regional) economic development.

The purpose of this study is to understand the outcome of new developmental interventions; i.e., VRCs and their linkages with a set of regional research institutions on the one hand, and with local farmers on the other hand.

24.2 Technology and Development: A Short Review

As economic activities have become increasingly globalized and knowledge-based, local communities across the developing world are apprehensive about their economic progress and increasingly rely on local institutions for their survival. Studies on innovation (using an innovation systems perspective) have assigned an important role for university–industry interaction in regional development. Studies in this genre generally fall into three categories: (i) studies that examine the capacity of firms to interact and make effective use of knowledge from universities (e.g., Cohen and Levinthal 1989); (ii) studies that analyzed the characteristics of universities that generate knowledge for industrial R&D and innovation (e.g., Henderson et al. 1998); and (iii) studies that analyzed the different channels through which knowledge flows from universities to industry (e.g., Cohen et al. 1998). It is important to note that most of the studies were concerned with the experience of industrial sectors in developed countries, and have not paid enough attention to the complementary institutions in the regions, other than enquiring about the channels of the flow of knowledge. Development processes are highly context-specific; and a thorough understanding of the local context is a prerequisite for successful and sustainable development interventions.

The evolutionary point of view on economic development argues that successful development involves co-evolution of knowledge and technologies, firms and economic structures, and a variety of non-market institutions (Nelson 2006b). Therefore, the basic challenge in the process of development for a region is to learn new ways of achieving things. Nevertheless successful development involves not only acquiring or learning new technologies, but also includes an painful process of creative destruction if the economic structures of these regions are to be transformed from less productive to relatively high productive economic zones. This depends on the institutional structure supporting economic activity and the extent to which they facilitate productive change (Nelson 2006a).

In agriculture, the break away or transition entails: (i) the introduction of an innovative crop that is new to the region; (ii) the diversification into high value-adding crops or agricultural activities; and (iii) the enhancement of existing production techniques through the infusion of new knowledge or techniques. In agriculture, extension activities are necessary to transfer information from a global knowledge base or from local research to farmers, enabling them to clarify their own goals and possibilities, educating them regarding better decision making, and stimulating desirable agricultural development (Van den Ban and Hawkins 1996). To warrant this transition, the capabilities for innovation must be strengthened, which requires the co-evolution of institutions. Institutional systems can, however, act to reduce risk and protect livelihood assets (Anderson et al. 1977).

ICT advances in space research can play a tremendous role in socio-economic development. It can be instrumental in disseminating knowledge of any kind to the rural masses and thereby can act as a catalyst to development. In the 1970s, multilateral organizations such as the Food and Agriculture Organization of the United Nations (FAO) began to implement a two-way knowledge flow and information exchange between rural communities and technocrats, rather than a one-way transfer of knowledge. This recognition that development comprises more than just increased productivity led to alternate development approaches, such as the Sustainable Livelihoods (SL) approach in the 1990s. This approach is centered on people and their livelihoods. It prioritizes people's tangible and intangible assets, and their ability to withstand shocks in the Vulnerability Context.[1] It also prioritizes policies and institutions that reflect priorities of the poor, rather than those of the elite (Chambers and Conway 1991).

In the issue at hand, VRCs are non-market institutions that assist local communities by means of creation and dissemination of knowledge. They are also the rural centers of knowledge management, where they manage raw information from different agencies and stakeholders, synthesize it, and add value before delivering it to the end users. The authors in this paper argue that these institutions are the primary source of new external knowledge to the local community, and significant actors in the local innovation system responsible for transition of the local economy.

[1] The Vulnerability Context refers to the seasonality, trends, and shocks that affect people's livelihoods. The key attribute of these factors is that they are not susceptible to control by local people themselves, at least in the short and medium term.

24.3 Structure of VRCs in Kerala

Since 2006, VRCs in Kerala are organized by ISRO in collaboration with the Kerala State Planning Board (KSPB) to serve as a primary delivery system in rural areas. Within Kerala state, it is generally known as the ISRO-KSPB Network. The ISRO-KSPB Meppadi VRC is designed to deliver services and knowledge on various subjects including health, education, agriculture, local weather, fisheries, environment, livestock keeping, livelihood support, family planning and other related trainings. VRCs also provide a variety of other services such as: price information, markets, pests and diseases, government schemes, e-governance related information, job opportunities, and a host of other ICT based services. They also act as local helplines. The VRC communication network uses a Very Small Aperture Terminal (VSAT) which can directly interact with the experts from various sectors of development through two way audio–video interactivity. It enables each expert node to multicast the information, and allows each of the participating VRCs to raise questions. Expert node software permits a video return link for each VRC and allows all participating nodes to listen to and view the expert and the questioner. The classes are well organized under the professional guidance of the governmental agency. In addition to the teleconferencing programs, additional features such as offline programs, soil testing and dissemination of weekly weather advisories have been undertaken for the benefit of the farming community in Wayanad. More than 90 % of the sample population in Meppadi depends on agriculture for their livelihood, whilst more than 60 % of their agricultural income is from coffee in all three groups.

24.4 Design and Methods

Both primary and secondary data are used for the study. The principal modes of data collection are field surveys, in-depth interviews (with three interview schedules) with: (i) different sections of VRC attending coffee planters; (ii) VRC non-attending coffee planters from the same village; and (iii) VRC non-attending coffee planters from neighboring villages as a control group. A detailed survey was conducted at Meppadi Panchayath[2] (11°33′38.24″N, 76° 8′31.32″E) of Wayanad district in Kerala state, India, during September and October 2011. In order to collect information regarding agricultural production practices, productivity and innovation performance, the authors collected primary data from 170 VRC

[2] *Gram panchayats* are local self-governments at the village or small town level in India. Panchayati Raj Institutions, the grass root units of local self-government have been considered as instruments of socio-economic transformation in rural India. As of 2002, there were about 252,000 *gram panchayats* in India. The *gram panchayat* is the foundation of the Panchayat System (PIB, Government of India 2009).

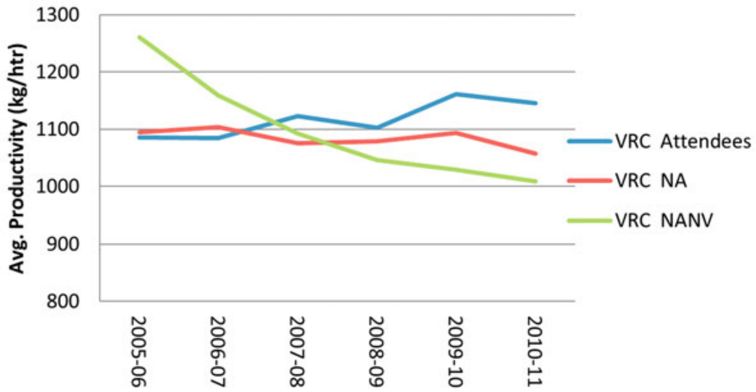

Fig. 24.1 Trends in average productivity of coffee for three groups

attending (VRC A) Meppadi coffee planters, 170 VRC non-attending (VRC NA) Meppadi coffee planters and 170 VRC non-attending coffee planters as the control group from neighboring villages (VRC NANV) such as, Ambalavayal (11°37′9.44″N, 76°12′37.72″E), Mooppanadu (11°32′7.45″N, 76°10′16.40″E) and Vaithiri (11°32′54.66″N, 76° 2′28.09″E). Meppadi is a high altitude interior region in Kerala state, with a largely tribal population and relatively lower levels of development indicators. Coffee in Wayanad (66,999 ha) shares 33.65 % of the total cropped area in the district and 78 % of the coffee area in Kerala state.

24.5 Empirical Results

24.5.1 Productivity

The average productivity of coffee plantation of the three different sample groups is given in Fig. 24.1. Productivity is calculated in terms of production in kilogram per hectare (kg/ha). The average productivity of VRC A was 1,086 kg/ha during 2005–2006; it fluctuated in the succeeding years and increased to 1,146.1 kg/ha in 2010–2011. In the case of VRC NA, in 2005–2006 average productivity was 1,094 kg/ha, declining to 1,057 kg/ha in 2010–2011. During this period, the productivity of VRC NANV also continuously declined from 1,261 kg/ha to 1,008 kg/ha It was also noted that the productivity of VRC A was higher than that of VRC NA since 2007–2008. From the field, it was observed that in these periods the interventions of VRCs were active in this region. This indicates the positive impact of VRCs in terms of productivity. VRCs ensure a greater access to information that improves the innovative capability of the local communities for appropriate development and planning for their scarce resources.

The productivity of coffee in Wayanad and Kerala had also declined since 2000–2001 (Government of Kerala 2003). Following this macro trend, many of the survey respondents also noted decelerating trends in productivity. A deeper analysis on the patterns of productivity decline across groups illustrates that more than 86.7 % of VRC NANV and 70.4 % of VRC NA reported decline in their productivity in the last 10 years.[3] On the other hand, only 33 % of VRC A experienced decline in coffee productivity since 2000–2001. Productivity decline is comparatively lower among VRC A than the other two non-attendees' groups primarily due to the strong intervention and support of the VRC during the last five years, in the form of new knowledge inputs and subsequent changes in farming techniques.[4]

24.5.2 Innovation Performance

This section primarily deals with the analysis of innovations introduced in plantations over time and examination of the role of VRCs in this process. The innovative changes are identified in terms of changes in farming and hiring practices; subsequently changes in farming practices are discussed in terms of changes in existing farming practices and adoption of entirely new processes or varieties. Figure 24.2 illustrates the innovative changes adopted by VRC A and VRC NA planters in Meppadi and neighboring villages during the last five years. It clearly shows that about 55 % of VRC A had undertaken changes in farming practices, whilst only 25 % of non VRC NA and 13.6 % of non VRC NANV have initiated modifications during the last five years. Major changes in the farming practices are in pruning, weeding, bio farming, application of pesticides and insecticides, adoption of new plants/varieties,[5] and crop switching.[6] In the field, the authors observed that innovative changes in farming practices as a result of new knowledge and learning were followed by subsequent changes in labor hiring practices. However, the consequent changes in the labor market were quite complex, as this had significant repercussions on different incentives including the incentive to innovate.

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[3] Figure 24.1 demonstrates that the VRC non-attendees (VRC NA) had experienced decline in productivity during last five years. During last five years VRC attendees (VRC A) marked no declining trends in productivity, however during 2001-2002 to 2010-2011 VRC attendees (VRC A) also experienced decline in productivity. It is noticeable that VRC was not functioning during this period of declining productivity.

[4] Innovative farming techniques adopted during the period are discussed in Sect. Sect. 24.5.2.1.

[5] Mainly in coffee, pepper, cardamom, rubber, banana, nutmeg, arecanut, cocoa, suppota and anthurium.

[6] Mainly towards rubber, as the relative market price of rubber had tremendously increased with respect to coffee, tea, arecanut and coconut.

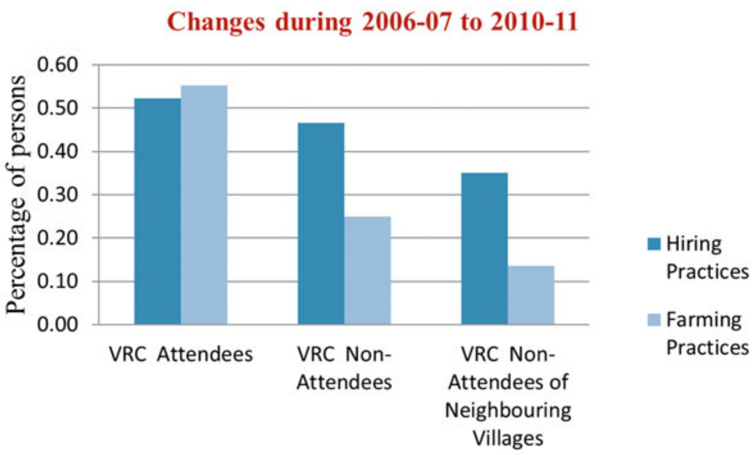

Fig. 24.2 Changes adopted in last 5 years

Table 24.1 Changes in existing farming practices during last 5 years

Farming Practices	VRC A (%)	VRC NA (%)	VRC NANV (%)
Weeding	46.1	19.8	2.1
Fertilizer application	45.1	20.61	7.4
Irrigation	39.9	16	1.1
Pest management	30.3	13.7	0.5
Harvesting	21.4	9.2	1.1
Post harvesting	11.2	4.6	1.1
Others	3.9	2.3	6.4

24.5.2.1 Changes in Existing Farming Practices

The authors identified major changes in existing practices in weeding, fertilizer application, irrigation, pest management, harvesting and in post harvesting techniques. Table 24.1 reports major changes adopted in existing farming techniques by each group during the last five years. The changes are reported under each major category for the three different groups, and show most of the changes in weeding, fertilizer, and irrigation techniques. The intensity of changes, however, varies acutely across the three different groups of planters. VRC A planters are primarily innovative in all major categories of farming techniques.[7]

[7] One example of changes in existing farming processes is in pruning. Previously coffee growers grafted coffee plants excessively, but now there has been a change in grafting practices. There has been a structural change on the extent and time of pruning. The change has increased productivity.

Table 24.2 Reasons for introducing changes in farming practices

Major reasons	VRC A (%)	VRC NA (%)	VRC NANV (%)
New knowledge	83	53	33
Less remuneration	2.3	7	5.3
Pests and diseases	5	20	22.3
Financial difficulties	1.2	–	5.3
Labor shortage	4.8	7	11.7
Others	0	0	10.6
Both new knowledge and less remuneration	3.7	13	11.7
Total	100	100	100

In the case of VRC A, more than 45 % of planters have adopted changes in weeding and fertilizer application during the last five years. The other major changes are in irrigation (40 %) pest management (30.3 %), harvesting (21.4 %) and post harvesting techniques (11.2 %). In comparison to VRC A, the performances of VRC NA and VRC NANV in the case of changes in existing farming practices are low. In all facets of farming practices mentioned above, the changes from VRC NA measures only half of that of VRC A.

Following the above reflection, one asks the important question about the motivations behind these innovations. The authors therefore envisaged a set of factors responsible for innovation in consultation with theoretical and empirical literature on innovation. The main incentives or motivations for these kinds of changes of both VRC attendees and non-attendees are depicted in Table 24.2.

From Table 24.2, it is clear that new knowledge is the key factor for innovations in plantations. However, it is also evident that this is due to significantly different reasons among the groups. Whilst it was the new external knowledge that induced innovations among VRC A, for the VRC NA, it was largely the problems associated with existing practices that compelled them to adopt the changes. Thus, it is imperative to understand what the main sources of knowledge are to the rural farmers. This will also help to understand the relative position of VRC as a knowledge provider, among alternative sources.

About 25.6 % of VRC A, 62.2 % of VRC NA, and 68 % of VRC NANV reported that traditional knowledge is the main source of information. In the case of VRC NA, ICTs are also an important source of information. It is important to note that almost 55 % of VRC A point out that traditional knowledge and VRCs are the main sources of information. Moreover, 8.2 % of VRC A population also revealed that VRC is their sole source of information. Two important facts that can be inferred from Table 24.3 is that: (i) VRC A farming community depends less on traditional knowledge sources compared to a VRC NA community; (ii) VRC ranks second among various local knowledge sources/institutions; and it is also noticeable that VRC attendees conceive VRC as a more reliable knowledge source than '*Krishi bhavan'*,[8] and it is also ranked higher than ICTs.

[8] *Krishi bhavan* is the government agricultural office at *Gram Panchayath* level.

Table 24.3 Sources of knowledge on farming practices

Sources	VRC A (%)	VRC NA (%)	VRC NANV (%)
1. Traditional knowledge	25.6	62.2	68
2. *Krishi bhavan*	3.4	6.9	12.9
3. ICTs-TV, internet, news papers, etc.	5.7	18.9	1.2
4. Suppliers of farm implements	0	0	6.6
5. Other farmers	0	8	11.4
6. Farm organizations/exhibition	1.6	4	0
7. VRC	8.2	0	0
8. Both VRC and traditional knowledge	55.4	0	0

Table 24.4 Innovative methods adopted in last 3 years

Frequency of changes	VRC A	VRC NA	VRC NANV
New varieties/new plants			
1	43	20	7
2	29	7	0
3	16	4	0
4	14	5	0
5	12	5	1
Total	265	91	12
New processes			
1	19	2	7
2	8	3	3
3	5	0	5
4	4	3	0
5	21	7	0
Total	171	55	28

24.5.2.2 Adoption of New Varieties/Plants and Processes

Table 24.4 reports frequencies of adoption of new varieties and/or plants, and new processes by farmers hailing from three different groups during the last 3 years.

The first section of Table 24.4 addresses the frequencies of varieties or plants, and the numbers of adoptions under each frequency. As can be noted, 43 VRC A have adopted one variety, but only 20 and 7 persons, respectively, in the case of VRC NA and VRC NANV. Among the VRC A, 29 persons adopted two varieties, 16 persons adopted three varieties; and the number of persons who adopted four and five varieties are 14 and 12 respectively.[9]

[9] The phenomenon was not only in coffee but also in other crops such as rubber, arecanut, pepper, cardamom, etc. Previously the cultivation of rubber was not at all possible in Meppadi, owing to climate conditions, but today some farmers have started to plant rubber. Many farmers have also started adoption of new plants and varieties such as coffee, pepper, cardamom, rubber, paddy, banana, nutmeg, arecanut, cocoa, suppota, anthurium, mangosteen, and rambutan.

There have been changes in farming processes also. Whilst 57 VRC A out of 171 have made innovative changes in farming processes during the last three years, only 15 planters amongst VRC NA and VRC NANV each have adopted changes in farming practices during the period. A concise and comparative picture of the innovation performance of VRC A and VRC NA of two regions during the last three years can be conceived from the aggregate figure provided in Table 24.4. While 265 adoptions of new varieties and/or plants and 171 adoptions of new processes were identified among VRC A, VRC NA have made 91 adoptions of new varieties and/or plants and 55 new farming processes during the period. On the other hand, the third group, VRC NANV, have no more than 12 adoptions of new varieties and 28 adoptions of new processes during the period. The authors can now conclude that the developmental interventions through VRC for about six years have allowed the planters to become acquainted with new knowledge, to learn, and to innovate.

24.6 Conclusion

VRC is essentially a knowledge providing institution, which aims to enhance rural livelihoods and ensure higher income and a better standard of living. The institution is a service that can harness technology to enhance livelihoods and skills for rural prosperity. This study focused on two key factors, namely, productivity and innovation, and specifically the role of VRC in enhancing these factors in order to determine economic progress and wellbeing. This role is identified and illustrated by capturing the innovation performance and productivity levels of VRC A and comparing and contrasting them with respect to VRC NA. This impact is primarily from the establishment of local linkages between VRCs and other local development initiatives or institutions, which enabled VRCs to establish a virtual local system of innovation. The findings of the study are also an impetus to the policy experiments with Public Private People Participation (PPPP) models.

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