IWMI Working Paper 162

Review Paper on 'Garden Kits' in Africa: Lessons Learned and the Potential of Improved Water Management

Douglas J. Merrey and Simon Langan

Working Papers

The publications in this series record the work and thinking of IWMI researchers, and knowledge that the Institute's scientific management feels is worthy of documenting. This series will ensure that scientific data and other information gathered or prepared as a part of the research work of the Institute are recorded and referenced. Working Papers could include project reports, case studies, conference or workshop proceedings, discussion papers or reports on progress of research, country-specific research reports, monographs, etc. Working Papers may be copublished, by IWMI and partner organizations.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI staff. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

About IWMI

IWMI's mission is to *provide evidence-based solutions to sustainably manage water and land resources for food security, people's livelihoods and the environment.* IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a tangible impact on poverty reduction, food security and ecosystem health.

IWMI Working Paper 162

Review Paper on ‘Garden Kits’ in Africa: Lessons Learned and the Potential of Improved Water Management

Douglas J. Merrey and Simon Langan

International Water Management Institute

The authors: Douglas J. Merrey is an independent consultant, Natural Resources Policy and Institutions Specialist, Pittsboro, NC, USA (dougmerrey@gmail.com). He worked for the International Water Management Institute (IWMI) for over 20 years, and was the first Director for Africa; and Simon Langan is a Principal Researcher - Agricultural Water Management and Head of IWMI's East Africa and Nile Basin Office in Addis Ababa, Ethiopia (s.langan@cgiar.org).

Merrey, D. J.; Langan, S. 2014. *Review paper on 'Garden Kits' in Africa: lessons learned and the potential of improved water management*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 60p. (IWMI Working Paper 162). doi: 10.5337/2015.202

/ water management / rainwater / water harvesting / domestic gardens / vegetable growing / guidelines / domestic water / households / wastewater / small scale farming / irrigation systems / drip irrigation / economic development / sustainability / food production / plant nutrition / gender / women / Africa / Africa South of Sahara /

ISSN 2012-5763
e-ISSN 2478-1134
ISBN 978-92-9090-812-8

Copyright © 2014, by IWMI. All rights reserved. IWMI encourages the use of its material provided that the organization is acknowledged and kept informed in all such instances.

Please direct inquiries and comments to: *IWMI-Publications@cgiar.org*

A free copy of this publication can be downloaded at www.iwmi.org/Publications/Working_Papers/index.aspx

Acknowledgements

This Working Paper was made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents of the paper are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States government.

Project

This research study was initiated as part of the Feed the Future Innovation Lab for Small-Scale Irrigation (ILSSI) project, a cooperative research project implemented through the United States Agency for International Development (USAID) in support of the Feed the Future (FtF) program.

Donors

This research was funded by the following:

United States Agency for International Development (USAID)

Contents

List of Figures

Acronyms

ACF	*Action Contre la Faim* (Action against Hunger)
AMG	African Market Garden
AOCC	African Orphan Crops Consortium
AVRDC	The World Vegetable Center
CARE	Cooperative for Assistance and Relief Everywhere
CRS	Catholic Relief Services
DWAF	Department of Water Affairs and Forestry (now Department of Water Affairs)
EHFP	Enhanced Homestead Food Production Program
FAO	Food and Agriculture Organization of the United Nations
FtF	Feed the Future (USAID program)
HED	Horticulture Easy Drip (kit)
HKI	Helen Keller International
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
iDE	Formerly International Development Enterprises, an NGO
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
ILSSI	Innovation Lab for Small-Scale Irrigation
IWMI	International Water Management Institute
KARI	Kenya Agricultural Research Institute
MICAH	Micro-nutrient and Health Program
MUS	Multiple-use water Services
PRISM	Poverty Reduction through Irrigation and Smallholder Markets
SEI	Stockholm Environment Institute
SSA	sub-Saharan Africa
UN	United Nations
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WRC	Water Research Commission of South Africa

Summary

Purpose
This paper has been prepared for the Innovation Lab for Small-Scale Irrigation (ILSSI). ILSSI is a cooperative research project implemented through the United States Agency for International Development (USAID) in support of the Feed the Future (FtF) program. The project aims to increase food production, improve nutrition, accelerate economic development and contribute to the protection of the environment. A research partnership comprising the International Water Management Institute (IWMI), the International Livestock Research Institute (ILRI), the International Food and Policy Research Institute (IFPRI), and North Carolina A&T State University, led by the Texas A&M University System is collaborating with national partners to achieve the goals of ILSSI.

The purpose of this paper is to synthesize available knowledge and lessons learned from past experiences in promoting kitchen or home gardens, with a special emphasis on water management. The paper has been prepared based on an extensive desk study. It focuses on gardens whose primary purpose is production of food and, at times, growing herbs and spices for home consumption. Home gardens defined in this manner are distinguished from market gardens. However, there is no firm differentiation: some home garden produce may be sold, while some market garden produce may be consumed by the household. Home gardens are an ancient and ubiquitous practice; most rural people have some kind of home garden. Home gardens tend to be characterized by the diversity of crops grown, recycling of nutrients including organic household wastes and grey water, and minimal use of purchased inputs. They are usually managed by women, often assisted by children. Home gardens do not exist in isolation: they are an integral component of larger agro-ecological, social, economic and cultural systems.

Home Gardens
It has been recognized for decades that agricultural growth itself does not necessarily lead to improved nutrition. Therefore, governments, donors, UN agencies and NGOs have been promoting home gardens to achieve better family nutrition for many years, mostly with positive results. There are now a large number of guidelines and manuals as well as specific programs; this paper reviews some of them. Home gardens are perceived as potentially important entry points for empowering women as well as enhancing nutrition and therefore improving the health status of mothers and their children. Studies have shown clearly that the most successful home garden programs take an integrated approach, involving the health, water supply and sanitation, agricultural and other sectors; they include strong capacity development and training programs related to nutrition and child care as well as gardening; and empowering women.

Only a few of the NGOs promoting home gardens for household nutrition have either implemented or commissioned impact evaluations. Most charities have either not carried out such evaluations or have failed to publish them. However, there are numerous evaluations of home gardens (as distinguished from specific home garden programs) and their impacts, and several careful reviews of case studies published over the past decade. In general, these studies confirm that people in households with productive home gardens do consume more nutritious fruits and vegetables, though most studies do not quantify the amounts consumed. Some studies confirm the positive impacts on the actual health status of children and mothers — but too few do this. Few home garden programs have adopted clear impact pathway models and even fewer studies have been able to trace the impact pathways clearly, from interventions to health outcomes. Nevertheless, it does seem plausible that well-designed home garden interventions lead to better

health outcomes, and there is evidence for their sustained impact. However, there is very little evidence on equity outcomes: do home gardens offer an effective entry point for empowerment of women? And does such empowerment contribute to healthier children? It seems plausible that the answer is 'yes' to these questions under some conditions, but there is very little specific evidence.

Water Management for Home Gardens

In the arid, semi-arid, and subhumid tropical regions – which includes much of rural sub-Saharan Africa (SSA) – water is a critical input to successful home gardening, and very often a critical problem affecting the year-round productivity of gardens. In principle, it is possible to grow vegetables year-round, even in the cold higher altitudes. But a ready source of water is needed during the dry periods to maintain crop growth. Where there is no source of water close to the garden, it is important to capture and store rainwater as well as household grey water. But for poor rural households with little ready cash to invest, what are the cost-effective ways of obtaining and applying water to their home gardens?

We examined available evidence on the following technologies: use of grey water and clay pots for irrigating gardens, bag gardens, keyhole gardens, and trench gardens. We were unable to find any evidence on the scale of use or the actual costs and benefits, impacts, and sustainability. There are a few studies of the outcomes of programs promoting rainwater harvesting combined with underground storage tanks, for example in Ethiopia; otherwise this too is a neglected area of research.

There are some studies of the impacts and sustainability of programs promoting low-cost low-head drip irrigation kits. Their findings are clear: in water-scarce areas, the use of good quality drip irrigation kits by smallholders cultivating high-value crops for assured markets, where farmers have access to adequate technical support, seems to be profitable and sustainable. However, the promotion of small low-cost kits to poor households producing for their own consumption with little access to functioning markets is neither profitable nor sustainable.

There has been very little research on the actual use of these water management technologies in people's gardens, and the actual outcomes in economic terms, sustainability, and gender outcomes. In other words, there is a need for more studies on the conditions and implementation strategies that would favor using home garden packages including water management interventions as entry points for achieving sustainable equity, food security and nutrition goals.

Recommendations

Based on the findings of this study, the paper strongly recommends avoiding single-dimensional approaches, for example testing specific technologies such as drip irrigation kits. Such research may produce another postgraduate thesis or published paper, but will contribute very little to finding ways to promote more productive and nutritious home gardens. The paper also recommends that researchers avoid making assumptions about the interest in and demand for specific water management or other technologies for home gardens. Instead, it recommends building on current home gardening practices, starting with diagnostic appraisals of actual gardening practices, and moving on to participatory action research focused on evaluating promising water management technologies and testing implementation strategies that empower women. In other words, follow a participatory demand-driven approach and avoid supply-driven research. Two components or thrusts of a possible research program are proposed.

The first component would be participatory diagnostic appraisals of actual home garden practices: what do people grow and why? What are the roles of women, children, and men in gardening? What is the actual productivity of the gardens? What do people do with their produce, including surpluses, if any? What are their actual water management problems and practices? What are the gardeners' own perceptions of the role of the garden and what do they see as the main constraints and problems? If water management is a problem, what kinds of solutions would be of interest to them? The paper recommends developing and testing a garden water management diagnostic methodology modeled somewhat on the *Participatory Rapid Diagnosis and Action Planning for Irrigated Agricultural Systems* (PRDA) manual. The products of this diagnostic activity would be: 1) diagnosis of issues that need to be addressed (setting the scene for the action research component); and 2) a handbook and training manual on participatory diagnosis and action planning process for home garden improvement.

Building on the first component, the paper recommends an action research component with three objectives: a) testing the acceptability and performance of some of the low-cost technologies reviewed in this paper through a participatory process; b) testing implementation strategies for promoting a 'menu' of garden water management practices that are not only effective in terms of adoption, but also have the potential to improve the lives and status of women; and c) adapting available training modules and curricula to the specific conditions where the research will be carried out. The outputs will be: 1) field-tested information on the performance and acceptability of specific technologies; 2) field-tested implementation strategies that contribute to women's empowerment; and 3) a field-tested garden water management training module based on the lessons learned that can be used by governments and NGOs promoting home gardens.

These two thrusts – the diagnosis and the action research – are best done in partnership with organizations with broader expertise and experience promoting home gardens. The water management technologies need to be appropriate to the crops grown and horticultural practices of the specific region where the work is done.

Home gardens play critical roles in enabling poor rural households to meet their food security and nutritional requirements, as well as enabling women to earn extra income. There are clearly opportunities to increase the productivity of home gardens, the consumption of nutritious food, and improving the lives of women and children using home garden improvements as the entry point.

1. INTRODUCTION: BACKGROUND, PURPOSE, OBJECTIVE AND METHODOLOGY

1.1 Background

This working paper has been prepared for the Innovation Lab for Small- Scale Irrigation (ILSSI). ILSSI is a cooperative research project implemented through the United States Agency for International Development (USAID) in support of the Feed the Future (FtF) program. The project aims to increase food production, improve nutrition, accelerate economic development and contribute to the protection of the environment. ILSSI is based on a partnership and engagement approach to ensure continual learning; responsiveness to local needs, demands, and realities; complementarities with national goals and initiatives; and the uptake of outputs and recommendations by farmers, researchers, policymakers and investors. The project will identify, test and demonstrate technological options and promote dialogue among stakeholder communities and policymakers. A research partnership comprising the International Water Management Institute (IWMI), the International Livestock Research Institute (ILRI), the International Food and Policy Research Institute (IFPRI), and North Carolina A&T State University, led by Texas A&M University System is collaborating with national partners to achieve the goals of the ILSSI.

1.2 Purpose of This Study

The ILSSI research partners are considering pilot testing home garden water management interventions in at least one country and possibly up to three countries in sub-Saharan Africa (SSA). The purpose of this working paper is to synthesize available knowledge and lessons learned from past experiences promoting kitchen or home gardens, with special attention to water management. Many donors and NGOs use various kinds of garden 'kits' to increase nutritional security at the household level, to support school programs, and to enable poor households earn additional income. However, the 'kits' vary widely in terms of their target users, content, prices, and whether or not they have an irrigation component. There are numerous studies on garden kits. This review paper examines a selection of current available literature on experiences with garden kits, with a special emphasis on garden micro-irrigation kits. The paper will be used as an input into deciding whether and where to pilot test garden interventions, and how to design any such test.

1.3 Methodology

This review is based on a desk study. The authors carried out numerous searches on the internet, primarily using Google™ and Google Scholar™. A variety of terms and combinations of terms were used including 'home gardens', 'kitchen gardens', 'bag gardens', 'drip irrigation kits', 'bucket and drip irrigation', and 'micro irrigation'. These searches were supplemented by searches of NGO and donor websites that might be supporting home garden programs in Africa, as well as private firms offering garden kits or garden irrigation kits. In addition, the librarians at IWMI carried out searches of several databases using a variety of search terms. The search was focused on Africa — inclusion of Asia and other regions would have added many hundreds more references. Nevertheless, we found well over 200 credible and useful papers of various kinds and a large number of websites with information on home or kitchen garden programs around the world, and specifically in Africa.

These references were classified and organized on the basis of the original outline of this paper; that outline has evolved somewhat into the current organization of this working paper. The references and websites form the database for the remainder of this working paper.

1.4 Concepts, History and Definitions: Home Gardens

Many terms have historically been used for what we are calling 'home gardens': examples include 'mixed', 'backyard', 'kitchen', 'farmyard', 'compound', 'household', and 'homestead' gardens. One program in West Africa uses the term 'health and nutrition garden' (McDermott et al. 2013). *The critical defining feature is their use to produce food for household or home consumption. Produce from the home garden may also be sold or given away to neighbors and relatives, but its primary purpose is production of food for the household. We use the term 'home garden' throughout this paper to refer to such gardens*. Home gardens defined this way contrast with 'market gardens' and 'field agriculture' (Niñez 1987). 'Market gardens', as the name implies, have as their primary purpose production for a market, though some produce is usually consumed in the household.

The various home garden synonyms refer to private gardens usually located within the homestead; hence terms like 'kitchen' and 'backyard' garden. They usually contain a diversity of plants, and often, but not always, recycle nutrients sustainably. They are usually quite small, though there is no precise definition of this criterion. Gardens are usually a supplemental not primary source of family consumption or income. Critically important, home gardens are a production system which requires few or no economic resources and therefore entry is easy for poor families: they are based on locally available planting materials, natural manures, and indigenous pest control methods (Marsh 1998; Mitchell and Hansted 2004, and others).

In some places one finds 'community gardens', i.e., multiple households' gardens located in one place and often but not always, involving some degree of inter-household cooperation. These are sometimes referred to as 'allotment gardens' as they involve allocation of a piece of land for noncommercial gardening (Weinberger 2013). They are common in urban as well as rural settings. In addition, many NGOs and governments promote school gardens as a means to teach children principles of gardening and nutrition as well as to produce nutritious food.[1] Community gardens may be used to produce food for home consumption or for the market, or both; school gardens, however, are not usually commercial. This paper includes some attention to experiences related to community and school gardens with special emphasis on their use for teaching (school gardens) and production for own consumption.[2]

Home gardens have an ancient history and are found in all parts of the globe (Niñez 1984, 1987; Marsh 1998). They are found in urban and peri-urban as well as rural areas. Oluoch et al. (2009) say there is widespread agreement among researchers that 90% of rural households in SSA have home gardens. As noted above, home gardens are generally characterized by their diversity; depending on local conditions they may include a wide variety of productive trees and shrubs, perennial as well as annual fruits, vegetables, nuts, medicinal plants, herbs, fodder, biofuel, and sometimes even staples. In both tropical and temperate zones, backyard gardens are often also used to house and support small animals such as poultry, rabbits, and goats and in some cases fish.

[1] http://www.fao.org/schoolgarden/ (accessed on January 6, 2015) is an FAO website with advice on establishing school gardens.

[2] Other types of "institutional" gardens for consumption purposes are also found, for example in prisons and hospitals. We did not find much information on these and therefore they are not covered systematically here.

There are two major ecological types of home gardens: tropical and temperate, with considerable internal variation and overlaps. Traditional gardens found in tropical climates are usually 'layered', with combinations of tall trees, medium height shrubs and short species that form an integrated, productive and sustainable production system for a wide variety of fruits, vegetables and other products. They are thus a form of agroforestry. The taller trees protect other species from the heat of the sun and from hard rain; and there is a constant recycling of vegetation to maintain the production system with minimal additional inputs. These have been especially well-studied in tropical Asian countries, (e.g., Niñez 1984, 1987; Kumar and Nair 2004; Kumar and Nair, eds. 2006); but in East Africa *chagga* home gardens have a similar multi-layered structure (Hemp 2005; Hemp and Hemp 2008).

In temperate as well as high-altitude tropical gardens, Niñez (1984, 1987) says that trees, shrubs and annual vegetables are generally well-spaced with little or no shading of groundcover. Further, there is a greater dependence on annual fruit and vegetable crops, which leads to seasonal changes in what is grown. Annual crops are rotated and intercropping is reduced compared to tropical gardens. Recycling of organic matter is also slower and less productive, so that supplementation is needed, for example from animal and household waste. These characteristics, however, are not universal: we found evidence of considerable diversity and layering, and use of trees, in temperate areas in South Africa and elsewhere; these are discussed below. The important point here is that home gardens exhibit a huge diversity and to be productive and sustainable they must be appropriate for the climate, culture, and household labor availability.

Landon-Lane (2011) describes African gardens as being multi-storied and diverse in humid areas, but becoming less complex and diverse in areas with lower or less reliable rainfall. Gardens become smaller and simpler in densely populated areas. In systems with more cash cropping, home gardens play even more important roles, often even used to grow staple crops such as sorghum, cassava, yams, groundnuts and oil crops. In the Sahel, where rainfall is especially irregular, compound livestock and tree gardens are important as they are less risky than field agriculture. Gardens are a strategic insurance against total crop failure; and such gardens often propagate themselves with little or no care.

There is a large and growing literature on urban and peri-urban gardening -- both commercial and home-use gardens, (e.g., Gockowski et al. 2003; Shackleton et al. [eds.] 2009; Drechsel and Dongus 2010; Gallaher et al. 2013). Home gardens are found in both modern highly developed cities and in the rapidly growing urban and peri-urban areas of the developing world; hence, NGOs and governments strongly encourage such gardens. They may be located within a homestead, in a neighborhood allotment, or even on rooftops. In the developing world, these are often irrigated using untreated wastewater. There is no strict segregation between commercial and home-use gardens. In this study we have focused entirely on rural home gardens, except that we have drawn on some studies of the impact of urban gardens on household nutrition.

In the dry and semi-arid humid tropics, (i.e., large parts of SSA), gardens need to be watered periodically. The water may be drawn from various sources including harvested rainwater, wells, domestic water supply, and household grey water or other wastewater sources. It may be applied using a variety of techniques, from buckets to drip or sprinkler irrigation kits. This study examines garden water management techniques in some depth.

Finally, in most African societies women are responsible for home gardens and usually for community gardens as well. Children of both genders are involved in school gardens. Women, assisted by children, nearly always manage home gardens for the production of fruits and vegetables and small livestock for home consumption, and frequently as a source of income from local sales. Although improving household food security and nutrition is a central goal for most households and for those promoting gardens, the opportunity to earn extra income can also be extremely important to the household, especially to the women (Weinberger 2013; Mitchell and Hansted 2004; Galhena et al. 2013; McDermott et al. 2013).

1.5 Conceptual Framework

Home gardens do not exist in isolation; in rural areas they are nearly always a component of a larger agro-ecological, socioeconomic and cultural system. The role of home gardens must be viewed in the context of the farming system and household economy (Marsh 1998; Kumar and Nair 2004). Therefore, it is important to avoid studying or promoting home gardens in isolation: their actual or potential roles in the larger scheme of things needs to be understood. These roles and their importance vary greatly depending on the context. Therefore, an integrated agro-ecological perspective is critical for any program to be successful in promoting home garden, (e.g., van Ginkel et al. 2013).

Promoting home gardens is often considered to be an effective approach to enhancing the well-being, food security and nutritional status of poor households, (e.g., Galhena et al. 2013; McDermott et al. 2013). There is evidence that rapid economic growth, including agricultural growth, alone does not necessarily lead to better nutritional outcomes, (e.g., Kumar and Nair 2004; Weinberger 2013). Home gardens are therefore seen as effective entry points for achieving better nutritional outcomes at household level; they are considered by their proponents to be a way of promoting nutrition-sensitive food systems. There is evidence that home gardens do lead to more diverse and nutritious diets, (e.g., Berti et al. 2004; Wenhold et al. 2007; Laurie and Faber 2008; Keatinge et al. 2011; Faber and Laurie 2011; Chadha et al. 2011; Weinberger 2013; Turner et al. 2013), though Turner et al. (2013) emphasize that the impact pathway to better nutrition is through diversified agriculture, not specifically through home gardens. In section 4.5, below, we discuss the weakness of evidence showing that improved diets lead to measurably improved health status.

McDermott et al. (2013), however, argue that production of nutritious food by itself is not sufficient to achieve good nutrition; it is important to follow an integrated approach, from production to actual consumption. They suggest four steps: 1) alignment of agricultural interventions with those in health services; water and sanitation and social protection; 2) accelerate 'learning for development' policies and investments; 3) build local and national capacity to innovate; and 4) empower women and disadvantaged communities. To this we would add that home garden interventions need to be undertaken in a landscape and agro-ecological systems perspective; indeed home gardens may be an effective entry point to achieving sustainable intensification of agriculture and improved human wellbeing. In addition, home gardens may offer an entry point for empowering women, though the evidence for this is mixed (van den Bold et al. 2013a).

1.6 Organization of the Report

The next section (2) provides an overview of home garden technologies and manuals. It reviews what we have learned regarding kits and manuals being promoted in SSA for creating or improving home gardens. Some of the technologies discussed such as bag gardens are *inter alia* water management technologies. Section 3 does the same thing for water management technologies and kits. Section 4 reviews a selection of home garden programs and projects and evidence for their impacts in SSA. Section 5 reviews the evidence for outcomes and impacts of programs promoting drip irrigation kits. The contents of all these sections provide the basis for the conclusions and recommendations contained in section 6. Appendix 1 provides information on some of the major suppliers of home garden water management technologies, especially drip irrigation kits, while Appendices 2 and 3 provide additional information on the technologies and programs discussed in this paper.

2. HOME GARDEN TECHNOLOGIES: MANUALS AND KITS

There are many types of home garden technologies being promoted by United Nations (UN) agencies, research institutions, NGOs, and others, often, though not always, accompanied by manuals, kits, and packages of inputs, to help the gardener get started. There are quite a number of home garden handbooks produced by the Food and Agriculture Organization of the United Nations (FAO) and others, as well as guidelines and advice for creating specific types of gardens, for example bag, vertical, trench and keyhole gardens. Most of these guidelines are aimed at enabling poor people to improve their own food security and nutrition status, though some overlap into advising on gardening for more commercial purposes. Appendix 2 provides a summary of the characteristics of the technologies discussed here.

2.1 Home Gardens: General Manuals and Guidelines

There are probably hundreds of manuals and guidelines for creating and promoting home gardens, not only in the developing world but in America and Europe as well. This section cannot be comprehensive; it reviews some of those found that have useful information and are accessible.

FAO has been promoting home gardens for decades and has produced a variety of manuals and guidelines (for example Marsh 1998; FAO 2001; Landon-Lane 2011; Mitchell and Hanstad 2004; Bhattacharjee et al. 2006).[3] FAO's focus has consistently been on improving household nutrition through home gardening. FAO (2005) and AVRDC (n.d.) are detailed manuals on establishing school gardens. In an FAO publication, Marsh (1998) argues that building on existing home gardening traditions is a low-cost and highly effective strategy to help poor families to improve their nutritional status and even earn income, since it relies on low-cost low-risk technologies adapted to specific, even hostile, environments. Marsh suggests a few key principles of successful gardening projects based on experiences to date:

- Build on indigenous knowledge, i.e., existing garden traditions;
- Minimize bio-physical, agronomic and economic constraints, i.e., use local solutions to production problems and minimize the need for purchased inputs;
- Integrate nutritional education and social marketing;
- Promote the economic benefits of gardening, i.e., do not exclude income generation
- Understand and strengthen the roles of women and children; and
- Gardens should be promoted as an integral part of an integrated food security strategy.

[3] See also the following website: http://www.fao.org/ag/agn/nutrition/household_gardens_en.stm (accessed on April 22, 2014).

These principles are endorsed by other home garden researchers, (e.g., Oluoch et al. 2009) and characterize other home garden guidelines.

Landon-Lane (2011), also an FAO publication, provides a more up-to-date overview of various kinds of gardens, including home gardens, commercial gardens and nurseries. This publication offers very useful advice for planning gardening programs and also provides sources for further technical support. In another FAO publication, Mitchell and Hanstad (2004) use the sustainable livelihoods framework to offer an extended argument on the ways in which poor people can improve their livelihoods through home gardening. These two references are excellent overviews of the advantages of home gardens and what kinds of actions are needed to promote them successfully. REACH (2008), a product of a United Nations partnership to assist governments with high burdens of child and maternal under-nutrition to scale up food and nutrition actions, also offers important advice on taking a more comprehensive approach to promoting local homestead food production.[4]

UNICEF (n.d.) and Bhattacharjee et al. (2006) are technical manuals for establishing home gardens focused on tropical Asia. Helen Keller International (HKI) has also been promoting home gardens in tropical Asia (not only in Bangladesh) for decades, and has produced important documentation based on its experiences, (e.g., HKI/Asia-Pacific 2001; HKI/Cambodia 2003). More recently, it has begun working in West Africa: in 2009 it initiated its 'Enhanced Homestead Food Production Program' (EHFP) in Burkina Faso with USAID funding; in this case it is partnering with IFPRI to measure its impacts (HKI 2012). HKI claims substantial initial success, but it is too early for IFPRI to have measured the actual impacts of its programs[5]. We discuss this program further in section 4.

Catholic Relief Services (CRS 2008), FAO (2001) and Share-Net (2009) are home or school garden manuals developed for African contexts. CRS (2008) is a manual based on the experiences of Catholic Relief Services (CRS) promoting gardens for home nutrition in Lesotho but it is broadly applicable in temperate and semi-tropical semi-arid zones as well. It has specific chapters on types of home gardens, (e.g., keyhole, trench and pothole (*zai* pit) gardens, soil fertility, seed selection, and pest control. FAO (2001) is a training manual for field workers who will be promoting home gardens for improved nutrition in Africa (there are companion manuals for Asia and Latin America). It is a detailed systematic step-by-step training course and technical guideline for promoting home gardens which would need to be adapted to the specific eco-agricultural, social and cultural context to be useful. Share-Net (2009) is a South African resource book and creative learning guide to support using school gardens as a way of teaching reading, thinking, and growing food using "used" water and materials at hand. Among other things it contains specific guidance on such topics as how to use domestic grey water to irrigate a garden, how to make a tower garden, trench garden and tire garden, companion planting to repel pests, and composting.

Finally, we highly recommend a comprehensive detailed guideline on promoting homestead gardens produced by a team supported by the Water Research Commission (WRC) of South Africa (Stimie et al. 2010a, b). The authors sought to identify interventions that would help people "get **more for their effort** in a cash-scarce situation" (Stimie et al. 2010a:13). They have built on a variety of previous experiences in South Africa and elsewhere to develop a detailed and very comprehensive approach to promoting homestead gardening for food security and improved nutrition through participatory community-based learning processes. Stimie et al. 2010a provide

[4] Renewed Efforts Against Child Hunger. See http://www.reachpartnership.org/home (accessed on April 22, 2014) for more information on this inter-agency UN program.

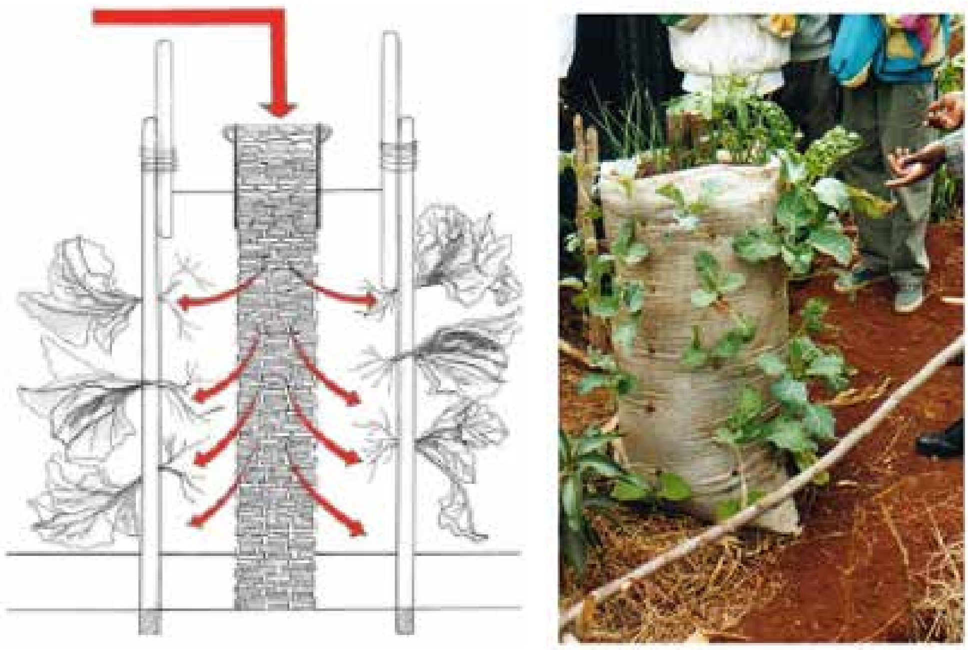
[5] The program includes promotion of drip irrigation kits (HKI 2012), but there is no information on actual experiences.

very detailed guidelines, activities, instructions and resource material accompanied by case studies and observations from the researchers' experience. The guidelines include both detailed technical information and – what makes this a unique handbook – detailed information on how to implement the overall learning and implementation process. While it was developed for South Africa, it is adaptable to other contexts as well.

2.2 Bag, Sack, Tower or Vertical Gardens: Vegetable Towers

This type of garden is especially appropriate when space, water supplies and funds are limited (Mati 2005). There are quite a few sources that describe how to construct a vegetable tower: Crosby (2005) has an illustrated description, which is also used in an enhanced form in Share-Net (2009); Stimie et al. 2010a also contains brief guidelines as does Mati (2005). IWMI (2010) describes its experiences promoting vegetable towers after the tsunami hit Sri Lanka in 2004. As described in this source, setting one up is simple and quick. A recycled poly sack (or 'gunny' sack) – a bag – is filled with a mixture of earth, sand and cow dung. A pipe with spirally placed holes or a plastic bottle with little holes in it is inserted into the middle of the sack. The vertical garden is irrigated by simply pouring water into the pipe or plastic bottle, from which it gradually seeps into the soil. The technique saves water because it is administered in trickles. Kitchen wastewater can be used, as it is already rich in nutrients. The sacks occupy very little space, the garden is portable, and labor input is minimal. IWMI (2010) estimates the cost of setting up a 48 cm by 168 cm vertical vegetable garden at US$10. Mati (2005) provides far less elaborate and less costly instructions, involving the use of a used 90 kg jute bag at a cost of approximately US$ 0.10. The watering shaft is made with three posts and packing straw and gravel in the center. Stimie et al. (2010a) also describe variations they refer to as 'tower gardens' and 'flat bag gardens' (see Figure 1).

FIGURE 1. Sketch of a tower garden and photo of a bag garden.



Sources: Share-Net 2009 for sketch; Water for Food Movement and IWMI (n.d.) for photo.

The instructions in Crosby (2005) and Share-Net (2009) are somewhat more elaborate but result in creating a larger, non-portable but more productive vegetable tower. Crosby notes that these gardens seem to resist the negative impacts of heat on production. We are not aware of any evaluations of their longer term success and sustainability in rural areas, but they seem to be a plausible garden technology. Gallaher et al. (2013) report on the expansion of sack gardens in Kibera, a large slum in Nairobi, Kenya. Their survey showed that they contribute significantly to household food security and nutrition, and also increase social capital for those who practice sack gardens in groups.

2.3 Keyhole Gardens

A keyhole garden is basically a round raised garden supported on its sides by stones, while underneath there are multiple layers of local composting materials. A central basket made of sticks is filled with grass and leaves and water is poured into it. The water disperses through the enclosed garden. A small pathway leading to the central basket allows easy access to the garden without bending—this is the 'keyhole'. The NGO 'Send a Cow' (http://www.sendacow.org.uk/keyhole-gardens/) is credited with its dissemination in many parts of Africa (see FAO 2008; and the Michigan State University website http://msue.anr.msu.edu/news/african_kitchen_gardens).[6] These three sources as well as the CRS (2008) garden handbook provide instructions on how to construct keyhole gardens; the Send a Cow site also has a video explaining the construction process of the 'keyhole' garden.[7]

Keyhole gardens are said to have many advantages: they can be used in dry semi-arid climates with poor soil (as well as in hotter and more humid areas); they are constructed using local materials; although their construction is somewhat labor-intensive, they require less labor to maintain than regular gardens and also use less water and no costly fertilizer; like vegetable towers they can be irrigated with household grey water. Their structure ensures soil fertility for five to seven years; and they can produce food year round even under harsh winter temperatures (such as those experienced in Lesotho). Because they can support a variety of vegetables simultaneously they enable diversified diets; and being prolific they can feed a family of eight (FAO 2008; CRS 2008). This technology is apparently widely used in Africa not only at household level but also in schools. Figure 2 illustrates the structure of a keyhole garden.

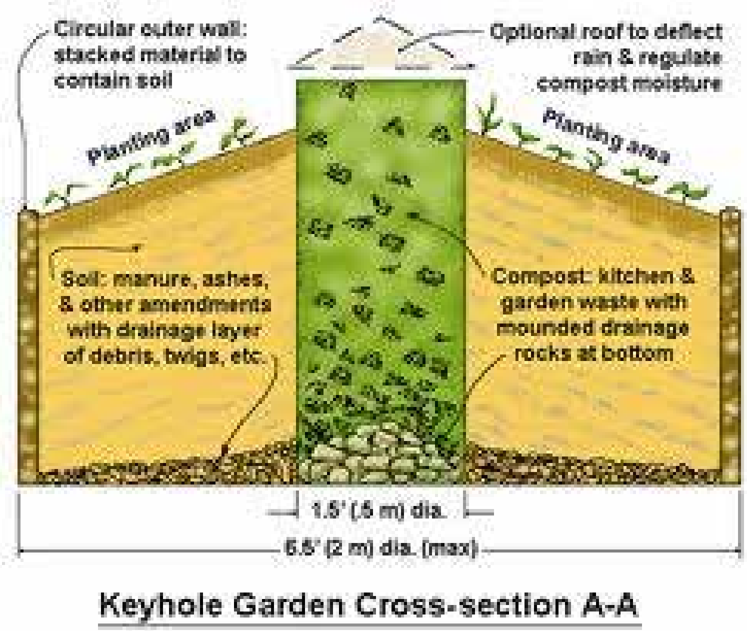
2.4 Trench Gardens

Deep trenching is a technique of permanent bed gardening that concentrates nutrients and water in the root zone (Stimie et al. 2010a).Trench gardens are based on the same principles and techniques as keyhole gardens, but instead of building a raised bed, the layers are dug into the ground leaving a small mound of topsoil. They share the advantage of retaining moisture and long-term maintenance of soil fertility, and also have the advantage of using fewer materials, requiring less labor to construct, and are able to accommodate larger plants. On the other hand, they require more space than a keyhole garden. CRS (2008) and Share-Net (2009) provide detailed instructions on the construction and use of trench gardens; Stimie et al. (2010a, b) also provide specific steps for constructing a trench garden and offer additional technical advice

[6] MSU says these are also called "African Kitchen Gardens." These sites were accessed on April 22, 2014.

[7] In fact keyhole gardens are popular in the Europe and the USA, and therefore there are numerous websites with instructions on their construction and use; see, for example, http://davesgarden.com/guides/articles/view/3726/ (accessed on April 22, 2014).

FIGURE 2. Cross-section of a keyhole garden.



Source: http://davesgarden.com/guides/articles/view/3726/

related to soil management. Denison et al. (2011b) contain detailed technical guidelines on their construction in the context of instructions on systematic rainwater harvesting (see section 3.1). Share-Net 2009 also describes the construction of 'tire gardens', another variation on the same theme. Trench gardens are not new, and there are many websites containing instructions for their construction. Stimie et al. (2010a) report that to their surprise the people they surveyed considered deep trenching to be the most significant of the menu of interventions they tested. Figure 3 is a photograph of a trench garden.

FIGURE 3. Photo of a trench garden.

Source: CRS (2008)

2.5 Seed or Nutrition Gardens and Kits

A major motivation for promoting home, school and community gardens is to improve the nutritional status of poor people, especially women and children. There are many manuals, handbooks and kits that focus specifically on promoting the consumption of nutritious vegetables, largely through the provision of seed kits. For example, the development and distribution of home, school and community garden kits in Asia and Africa is a major thrust of the program of the World Vegetable Center (AVRDC; www.avrdc.org; see, for example, AVRDC 2012). Its focus is on promoting production and consumption of nutritional vegetables. In South Asia and Africa, AVRDC promotes 'healthy diet gardening kits'. The African kit contains 14-17 kinds of high-yielding and nutritious vegetables, with enough seed to plant a home garden and provide a healthy diet for a family of eight for a year. The seed for kits is supplied by partners who assemble home garden seed packs for local needs (http://avrdc.org/?page_id=240 [accessed on April 22, 2014]; Chadha and Olouch 2007). We discuss AVRDC's program further in section 4.

A related thrust is the promotion of indigenous or traditional African leafy vegetables, which are said to be highly nutritious and well-adapted to African conditions, (e.g., World Bank 2002; Oniang'o et al. 2008 and many articles therein; van Rensburg et al. 2007; Laker 2007; Hart 2011; Oelofse and van Averbeke 2012; WRC 2013). van Rensburg et al. (2007) reviewed the consumption of a number of indigenous (and 'indigenized') vegetable varieties in South Africa. They found that while leafy vegetables are important components of people's diet in rural and urban areas, there is no clear trend in the use of indigenous varieties, largely because there is no effective support system to promote their cultivation and consumption. Similarly, also based on research in South Africa, Hart (2011) argues that while African indigenous vegetables are better suited to the difficult growing conditions found in many places, extension services need to be re-focused to support their cultivation. He found that extension services were promoting exotic vegetable and irrigation packages (the exotic varieties need to be irrigated) with limited success. Cultivation of the more hardy indigenous vegetable varieties was declining. In 2013, the African Orphan Crops Consortium (AOCC) launched the African Plant Breeding Academy, dedicated to supporting research on neglected crops, especially 100 crops referred to as the 'back garden' crops of rural Africa (http://www.worldagroforestry.org/aocc). It is premature to assess its potential contribution to promoting garden seed kits.

2.6 Agroforestry Gardens

In all regions, a variety of trees and shrubs are often integral components of traditional home gardens. Such gardens have ancient roots. They had been documented long ago, (e.g., Mergen 1987; Niñez 1984, 1987). A great deal of research has been done on agroforestry-based gardens, much of it by the World Agroforestry Center.[8] Indeed, one older World Agroforestry Center publication asserts that "most home gardens are agrosilvopastoral systems consisting of herbaceous crops, woody perennials, and animals" (Nair 1993). Including trees and shrubs significantly increases the benefits that households can derive from home gardens: not only annual vegetables but also fruit, fodder, firewood, shade, enhancement of soil fertility, and other products and services (SIANI and FOCALI 2014).

[8] A list of sources available on the World Agroforestry site: http://www.worldagroforestrycentre.org/search/google/garden?query=garden&cx=009242321525858492011%3Akcaxdcf_pzg&cof=FORID%3A11&sitesearch=&safe=medium (accessed on April 22, 2014).

Kumar and Nair (2004) summarize existing knowledge of home gardens based on agroforestry. A basic characteristic that is also confirmed in various case studies is that agroforestry gardens are characterized by a huge diversity of species. Kumar and Nair suggest that such gardens are sustainable over the long term because of efficient nutrient cycling made possible by their being multi-species, conservation of 'bio-cultural diversity', 'product diversification' and a host of both market- and non-market valued products. The preponderance of the available studies of agroforestry gardens are focused on tropical Asian and to a lesser extent Latin American cases; for example, all but one case in Kumar and Nair, (eds.) (2006); are Asian and Latin American; there is one case study from Ethiopia (Abebe et al. 2006 see also Abebe 2013). Other African case studies include Zemede and Ayale (1995), Haileselassie et al. (2012), and Tsegazeabe et al. (2012), all Ethiopian; Paumgarten et al. (2005; South Africa); and Maroyi (2009; Zimbabwe). Nevertheless, as Kumar and Nair (eds.) (2006) observe, agroforestry-based home gardens are common elsewhere as well, including much of Africa.

System descriptions, i.e., inventories of the many species grown and their uses, are the most common type of study of agroforestry home gardens (Kumar and Nair 2004). This is certainly true for the case studies from Ethiopia. For example, in a study of agroforestry-based home gardens in southern Tigray, Haileselassie et al. (2012) found over 40 species being grown, and document the importance of these gardens for household livelihoods; they provide a list of the species found and their uses. They also found a high correlation between the diversity of vegetables (leafy, fruit and root and tuber crops, spice and herbs in combination) and the availability of water. Zemede and Ayale (1995) provide detailed descriptions of agroforestry-based home gardens in various agro-ecological zones of Ethiopia. A recent study of enset-coffee agroforestry gardens in southern Ethiopia found that proximity to urban markets led to a reduction in the diversity of species grown as people shifted from food to cash crops. Similarly, larger farm size led to an increase in the cash crops at the expense of enset, the staple food. As these are high potential agricultural areas, the authors recommend integrating other high-value productive crops such as fruits, spices and vegetables into the gardens to maintain their complexity and diversity (Abebe et al. 2013).

Paumgarten et al. (2005) provide a detailed description of the trees planted in home gardens in two villages in each of two South African provinces. While there were many differences, a common finding was that water scarcity was named as the major constraint to tree cultivation across the board. Maroyi (2009) found that most households studied in Zimbabwe had two types of home gardens:1) 'homefields' adjacent to the homestead, often referred to as 'orchards' where mostly various kinds of trees are grown; and 2) garden plots located near water sources, usually wetlands (*dambos*) or near a stream, for growing vegetables year-round. The latter can be either individual or communal. Some people also had small vegetable gardens near their homes which they irrigated with household grey water.

A specific type of agroforestry-based garden is found in sub-montane East Africa called 'chagga' home gardens (Hemp 2005; Hemp and Hemp 2008). Chagga gardens are multi-layered gardens that retain the structure, functions and many of the species characteristic of the indigenous sub-montane evergreen forests that they often replace. For example, chagga gardens near Mount Kilimanjaro, Tanzania, often contain as many as 500 species of vegetation, of which 400 are natural vegetation species.

Based on the survey of literature and the examples cited here, including trees and shrubs in multi-species, home gardens can improve their productivity, sustainability and overall value to households. But, as several studies note, water availability is no less critical for trees and shrubs than for vegetables.[9]

[9] This is the case even in the vegetable-agroforestry systems of tropical Southeast Asia; see Catacucan et al. (eds.) 2012.

3. HOME GARDEN WATER MANAGEMENT TECHNOLOGIES AND MANUALS

There are many techniques to manage both overabundant and scarce water supplies for gardening. In wet areas, raised beds, drainage canals, and cultivation of water-loving plants are options; in dry areas use of mulching, ground cover and other water-conserving horticultural practices, cultivation of drought-tolerant plants, irrigation using household wastewater and seasonal gardening are common options (Marsh 1998). Mati (2005) provides a fairly comprehensive and very useful survey of water and land management techniques used at watershed, farm and household levels with an emphasis on East Africa. This section selectively reviews a subset of these options, focusing on techniques to gain access to water, store water, and apply water to crops, with an emphasis on the latter. Technologies to lift and transport water, for example using watering cans or buckets and human-powered or externally-powered pumps are also important, but are covered only briefly as they relate to drip irrigation. This section discusses recent work on household rainwater harvesting (including grey water) for use in home gardens; and the use of clay pot and drip irrigation for applying water to the root zones of crops in home gardens. We include household rainwater harvesting because there has been promising recent research about this practice, especially in South Africa; and the use of grey water as it is ubiquitous; we examine the use of pot irrigation, which seems promising under some conditions; and we pay most attention to drip irrigation kits for home gardens because of the large number of programs researching and promoting this technology in Africa. Section 5 returns to this topic where evidence for the performance and impacts of drip irrigation kits for home gardens is discussed.

3.1 Homestead Rainwater Harvesting and Storage

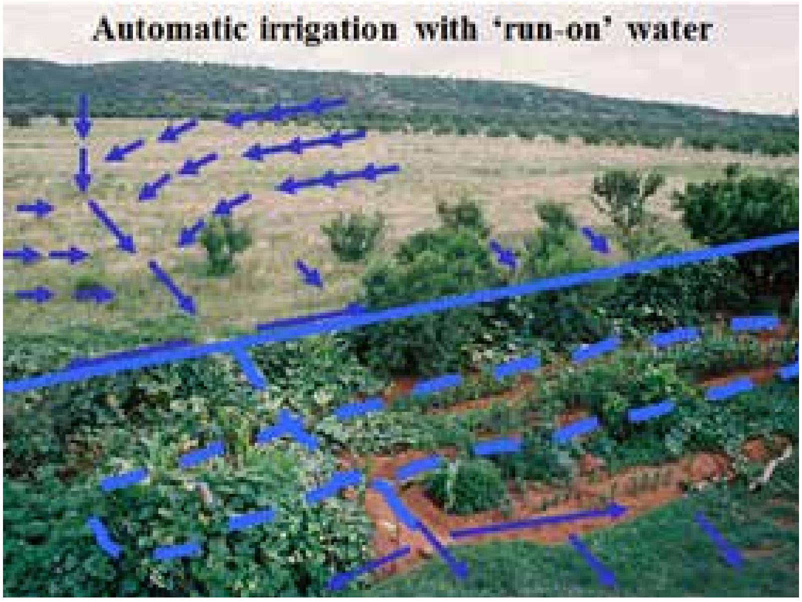
Capturing runoff from rainfall either to divert water directly to crop root zones or to store it for future use is an ancient technology (UNEP and SEI 2009). It is practiced at multiple levels including the household level. At household level, methods for capturing water range from shaping the land around the household to direct water onto fields or into underground storage tanks, to harvesting water from rooftops and storing it either in above-ground or underground tanks. A major impediment has always been the high cost of storage facilities relative to the low incomes of households. For example, Mati (2005) reports that the cost of concrete or brick-lined 20-50 m^3 underground tanks in semi-arid areas of Kenya is about US$190. Plastic-lined tanks are said to be easier to construct and cheaper as well (see Figure 4). Various research organizations, NGOs and governments have supported research intended to reduce the costs of constructing storage tanks; and both NGOs and official government programs often provide technical support and subsidies to enable households to build storage facilities, (e.g., South Africa [DWAF 2007]; Ethiopia [Merrey and Gebreselassie 2011] and Kenya [Ngigi 2003]).

In the mid-2000s, partly in response to events at the World Summit on Development in Johannesburg in 2002, the South African Department of Water Affairs and Forestry (DWAF) commissioned a study on how the Department could cost-effectively promote household food security through support for household rainwater harvesting and storage. The work built on the experience of a well-known grassroots activist, Ma Tshepo Kumbhane, founder of the Water for Food Movement (an NGO). She had pioneered low-cost self-help methods of mobilizing and motivating women to adopt rainwater harvesting for home gardens. Rainwater can be harvested and directed to the garden or to storage tanks (see Figure 5). The DWAF program experimented

FIGURE 4. Plastic-lined tank in South Africa.

Source: Water for Food Movement and IWMI (n.d.)

FIGURE 5. Homestead rainwater harvesting – MaTshepo's garden, South Africa.



Source: Water for Food Movement and IWMI (n.d.).

with underground storage technologies as well and arrived at a design for 30,000 liter underground tanks lined with bricks or blocks (Figure 6). But the study went further than developing the technical standards for water harvesting and storage structures: the guidelines provide a detailed set of instructions and teaching materials for mobilizing communities, providing training on basic nutrition and gardening techniques as well as on construction, use and maintenance of the household structures (DWAF 2007). The Department implemented a subsidy program for a few years but later abandoned it, apparently because it was viewed as too costly.

FIGURE 6. Cement block lined underground tank, South Africa.

Source: Water for Food Movement and IWMI (n.d.).

More recently, the Water Research Commission (WRC) of South Africa has published a detailed multi-volume comprehensive learning package for education on the application of water harvesting and conservation (Denison et al. 2011a-e). Many of the techniques described in the learning package are specifically for household garden use. For example, specific technical guidelines are provided for constructing diversion trenches to carry water to storage tanks, roof water harvesting, and above-ground and underground storage tanks, with detailed curricular and handouts for training people in these techniques. Although it is aimed specifically at South African conditions, this comprehensive learning package can be adapted to use throughout sub-Saharan Africa.

Ethiopia provides an example of a country making major investments in rainwater harvesting at multiple levels. Lakew Desta et al. (2005a, b) is a detailed training manual for community-based participatory watershed development that also contains detailed instructions on construction of a wide range of rainwater harvesting and storage technologies. These include household underground tanks and cisterns. With regard to household storage tanks, the Ethiopian Government (especially the Regional States of Tigray and Amhara) has in recent years strongly promoted the construction of such tanks. The sizes, shapes, lining materials (concrete, clay, plastic [geo-membrane]) and uses of rain water management ponds vary considerably. Uses of the water are multiple: irrigation of high-value vegetables, fruits, and seedlings, watering livestock, and household use including home gardens. Merrey and Gebreselassie (2011) reviewed the literature on these programs and found mixed experiences. But the problems seemed largely to be a function of the mode of implementation, which was often driven from above with local 'Development Agents' being given quotas that they must fill. There is, however, considerable evidence that they can make a significant contribution to household food security.

An international NGO, iDE (formerly International Development Enterprises), has tested and developed a variety of technologies for water storage (iDE 2011), which it offers for sale. The catalogue offers basic descriptions of five kinds of storage technologies, and advice on the relative costs (though not actual specific costs) and the advantages and disadvantages of each.

iDE is also seeking opportunities to test a plastic 200-liter storage bag costing US$5.00 to replace normal US$20.00 drums used for drip irrigation kits.[10]

Ngigi et al. (2005) assessed the performance of small on-farm ponds in Laikipia District, Kenya, a semi-arid area where evapotranspiration rates are high. High seepage and evaporation losses were so serious that many farmers were abandoning their ponds. Ultra-violet resistant plastic lining combined with covering the ponds with plastic reduced losses significantly. Construction costs were about US$300.00 for a 100 m^3 lined pond. Ngigi et al. (2005) conclude that combining these ponds with the use of low-cost drip irrigation kits gives a good return — but this assumes commercial cultivation of high-value vegetables.

Use of Household Wastewater

Household grey water, i.e., water that has been used for washing food, clothes, and people, is an important but often under-used source of water for home gardens. It can be stored and used when needed to irrigate tree crops and even vegetables. Crosby (2005) suggests it be used in tower or bag gardens. However, a detailed field study supported by WRC (Rodda et al. 2010, 2011) cautions that grey water must be used carefully as it may contain chemicals harmful to the soil and groundwater as well as human health: they suggest using only laundry wastewater, or kitchen wastewater, after basic treatment. On the other hand, they note that irrigating gardens with wastewater did lead to faster growth and somewhat higher yields in their experiments.

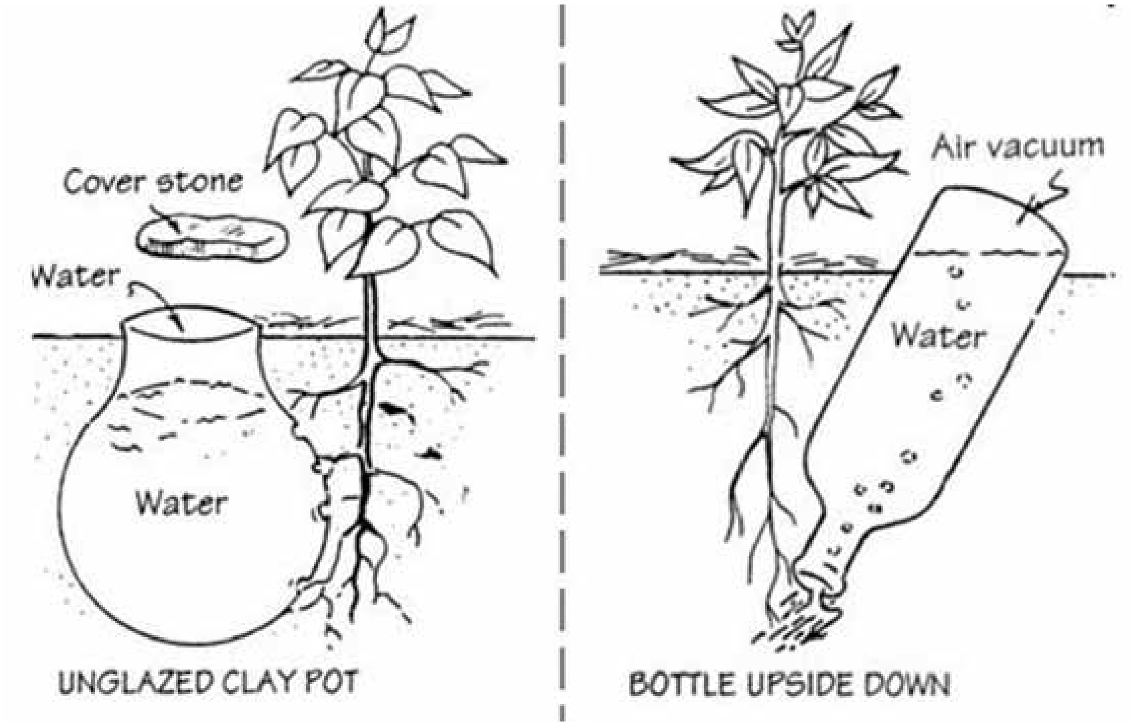
3.2 Clay Pot or Pitcher Irrigation

Use of buried unglazed clay plots, often called 'pitcher irrigation', is another very ancient irrigation technology appropriate for home gardens, especially in dry areas (Mati 2005; Bainbridge 2001, 2002, 2011, 2012). Mati (2005) describes their construction in Kenya: women use clay mixed with sawdust to ensure the pot is porous; sometimes small holes may be drilled in the pot. The pot is buried near the root zone of trees (or other crops), filled with water, and covered to prevent evaporation. The water seeps slowly through the porous sides of the pot, and minute hairs on roots pull the water out. Pitcher irrigation encourages deep rooting and reduces evaporation: it not only saves water but saves labor too; and it has fewer technical problems than drip irrigation. A variation described by Mati (2005) is 'bottle-feeding' of tree seedlings. In this technique, a bottle is filled with water and sealed (Figure 7). A small hole is punched into the top and the bottle is inserted top-first into the root zone at an angle. It needs to be refilled every few days.

Although Mati (2005) suggests this method is appropriate mainly for tree crops, Bainbridge (2001) argues it is appropriate in dry areas for other crops as well, including annual vegetables such as tomatoes and melons. The pots can also be used to irrigate seedlings. Bainbridge has been promoting clay pot irrigation for many years and provides detailed guidelines for their manufacture and use. He argues they are more robust and effective than drip irrigation. They are most appropriate where water conservation is important, especially for producing high-value crops in dry lands; they are also useful in areas affected by salinity or where only saline water is available for irrigation. He also suggests that clay pots are useful for container gardens (Bainbridge 2011, 2012).

[10] http://www.ideorg.org/OurTechnologies/WaterStorageSystems.aspx (accessed on April 22, 2014).

FIGURE 7. Sketch of clay pot and bottle irrigation.



Source: http://www.infonet-biovision.org/default/ct/293/soilConservation

In a review of micro-irrigation technologies in use in Zambia, Daka (2006) lists clay pot irrigation as a 'best bet' technology, especially for rural women. He estimates the cost at about US$1.00/pot, which lasts up to ten years. They are easily installed and used. He mentions an entrepreneur who was planning to mass produce and sell clay pots specifically for home garden use. He also notes that empty pots can be used to drain saturated soils. Abu-Zreig et al. (2006) describe laboratory tests of the auto-regulatory performance of two groups of pitchers, those with high and low hydraulic conductivity, and confirms their differing seepage rates under various evaporation conditions. Tesfaye et al. (2011) found that clay pot irrigation with nitrogen fertilization of tomato plants in Ethiopia is far more productive and water-efficient than furrow irrigation. Clay pots can be seen as a type of drip irrigation (Daka 2006). Pachpute (2010) studied the performance of clay pot irrigation combined with manure application and mulching for growing vegetables in Tanzania. The pots are inexpensive (US$ 0.75 each), the technology is easy to understand and use, and the package was found to reduce water and labor use significantly.

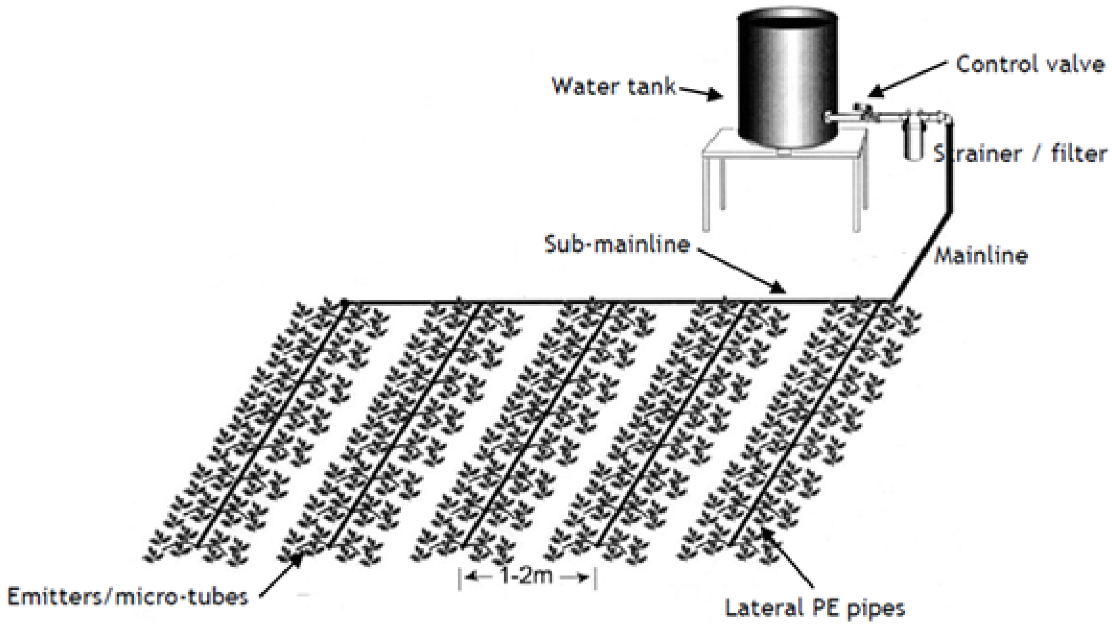
We have not found any systematic research evaluating the uptake, performance and sustainability of clay pot irrigation, nor have we found any studies on customer satisfaction.

3.3 Drip Irrigation Kits

There is a very large literature available on drip irrigation for smallholder farmers in Asia and Africa, reflecting the strong interest over the past decade or so by manufacturers, NGOs, governments and farmers. For commercial farmers there is little doubt about the relatively high performance of drip irrigation: in general, it saves a substantial amount of water and labor, increases yields, and often also improves the quality of the produce. It is used for tree crops as well as high-value annual horticultural crops. Because of its demonstrated high performance for commercial farmers, there has been an immense interest in developing and promoting low-cost low-pressure drip irrigation kits appropriate for small gardens. Indeed, some prominent scholars have argued strongly for a major international initiative to promote low-cost drip irrigation kits as an avenue to achieve significant gains in food security rapidly and cost effectively (Postel et al. 2001). By about the year 2000, a number of organizations had developed and were actively promoting 'affordable' drip systems. For example, a bucket and drip kit to irrigate 100 plants over 25 m^2 was being marketed in India for about US$5.00. Shah and Keller (2002), based on experiences in South Asia, argued that it is an effective way both to help women improve their food security and incomes (Nepal), and to help small commercial farmers in very dry areas (India). Thirteen years after the article by Postel et al. 2001 and millions of dollars of expenditure, the actual experience with affordable drip irrigation kits for poor rural farm households remains mixed, with both successes and disappointments.

This section focuses on small-scale or 'family' drip irrigation kits, and reviews a selection of the available manuals for using drip kits. We reserve discussion of studies of their performance for section 5. Appendix 1 reviews some of the vendors of this equipment. In general, these kits are a complete unit with a bucket, drum or tank placed about 1-1.5 m above the ground, a valve to control the flow (simple on-off in basic units), a screen to filter the water, plastic water distribution lines, dripper lines, and emitters (or micro-tubes or drippers) (see Figure 8). They operate by gravity. They are usually designed for areas ranging from 25 to 500 m^2; some are modular, enabling expansion over time. Because they are made with lower-cost materials, they are cheaper than conventional commercial drip irrigation systems; but they are also less robust as a result.

FIGURE 8. Sketch of bucket and drip irrigation kit.



Source: http://www.sswm.info/category/implementation-tools/water-use/hardware/optimisation-water-use-agriculture/drip-irrigation

The FAO has published manuals on pressurized irrigation systems including drip irrigation (Phocaides 2000, 2007). While the first edition did not discuss low-cost low-pressure family drip irrigation systems, the second edition (Phocaides 2007: chapter 15) has a short chapter on these systems. The Kenya Agricultural Research Institute (KARI) has been a pioneer in testing and promoting affordable drip irrigation kits, and has also published manuals (Sijali 2001; 2009). Sijali (2001) is a comprehensive early manual; Sijali et al. (2009) is a manual for 'eighth and quarter acre systems'. These are intended for small commercial farmers, not home gardens. The World Vegetable Center (AVRDC) has published a drip irrigation manual for simple drip irrigation for vegetables (Palada et al. 2011). Although developed for Asia, its detailed easy-to-follow illustrated step-by-step instructions for installation, use and maintenance are applicable elsewhere. It has a chapter on simple drip irrigation kits based on the iDE technologies; but it also has chapters on other low-cost low-pressure systems, for example, the 'Horticulture Easy Drip' (HED) system. Most important, it provides the most complete instructions for the installation and use of these kits.

iDE (n.d.) has published a technical manual for micro irrigation kits including both drip and sprinkler systems.[11] iDE and its founder Paul Polak have been the most prominent developers and promoters of affordable micro-irrigation technologies for achieving poverty reduction and food security in developing countries (we return to this below). The technical manual is an illustrated description of the advantages of these systems, their components, types of systems, instructions on their customization, and maintenance and trouble-shooting (but not how to grow crops). iDE offers four types of kits: 1) a 20 m^2 'Family Nutrition Kit'; 2) 100 m^2 'Vegetable Garden Kit'; 3) 500 m^2 'IDEal Drip Kit'; and 4) the 1,000 m^2 'IDEal Drip Kit'. The Family Nutrition Kit, the simplest and lowest cost, is intended for home gardens and very small commercial farms. Similarly, iDE offers four types of micro-sprinkler kits, though the smallest is designed for a 144 m^2 garden (iDE n.d.).

Pressurized drip irrigation systems by definition require pumping. However, even the low-pressure ones require a way to pump water up and into to the drum or tank. Therefore, various kinds of pumps are normally promoted to accompany these kits: treadle pumps, manual pumps, rope pumps or motorized pumps. When considering the promotion of drip irrigation kits for home gardens it is critical to pay attention to the availability of water, its quality (suspended solids and salinity) and the means to fill the bucket or drum.

We discuss the performance and outcomes of drip irrigation kits in section 5.

4. HOME GARDEN PROGRAMS AND PROJECTS IN SUB-SAHARAN AFRICA

There are numerous programs and projects promoting home gardens in sub-Saharan Africa. They range from very small initiatives of NGOs, often local ones, to large-scale programs promoted by international NGOs using donor funds. There are also government programs that are relevant for home gardens, such as the below-ground ponds promoted by the Ethiopian Government mentioned above. The concentration here will be on those promoted by international NGOs as these are the most prevalent and best-documented.

Home garden programs generally have multiple goals: household food security, improved nutrition especially of children, and opportunities to earn extra income, especially for the women

[11] This manual was apparently financed by the Challenge Program on Water and Food.

who invariably manage home gardens. This review summarizes the main characteristics of a few home garden programs. It does not pretend to be comprehensive, but captures the main thrust of most existing programs. Appendix 2 includes a summary of basic data on selected home garden programs.

4.1 AVRDC - The World Vegetable Center

AVRDC promotes home gardening in sub-Saharan Africa and South Asia through its '**healthy diet gardening kits', which are** designed to improve family nutrition. The kits are typically used in training programs to promote home gardening, as well as being distributed in the wake of natural disasters. Local food preferences and agronomic conditions are taken into account when seed is selected for the kits. The African kit contains from 14 to 18 different kinds of high-yielding and nutritious vegetables, with enough seed to plant a 36 m^2 home garden and provide a healthy diet for a family of eight for a year (about 170-250 kg of vegetables) (Ojiewo et al. 2010). Chadha and Olouch (2007) report that over 10,000 poor households in East Africa received these kits, financed by various donors; 'preliminary feedback' suggests they are being adopted and a reduction of micronutrient and protein deficiencies is observed (see also Chadha et al. 2011). The distribution of the kits is generally accompanied by education on basic nutrition as well as instructions on how to grow the gardens. The AVRDC also has a 'Vegetables Go to School' project, being implemented in six countries, which takes a school garden-based approach to improving nutrition of the students and their households (AVRDC n.d.).[12] The authors were not able to find any evaluations of impacts of AVRDC's kits, which is somewhat surprising as AVRDC is an international research center.

4.2 Helen Keller International

Helen Keller International (HKI) began promoting homestead food production in Bangladesh in the late 1980s and early 1990s. Over the years it expanded its program to other Asian countries and more recently has begun working in Africa – specifically Burkina Faso (HKI/Asia Pacific 2001; HKI 2012; McDermott et al. 2013). The HKI programs seek to increase the production of vegetables and fruits year round. Their Asian programs have been relatively large scale, (e.g., 800,000 households in Bangladesh in 2001) and low cost (US$5.00 per household) because they are implemented through local NGOs. Like AVRDC, HKI promotes a package including technical and managerial support and start-up supplies, seeds, seedlings, saplings and chicks. Over time, HKI added small livestock and fish to the package because of their nutritional significance. Local NGOs integrate homestead food production into their ongoing activities.

HKI has been continuously monitoring the impacts of its homestead gardening programs in Asia. HKI/Asia Pacific (2001) presents considerable data to support its claims that its programs in Asia have had demonstrably positive impacts on the production and consumption of nutritious vegetables and fruits, reduction of night blindness in children, and children's intake of vitamin A.[13] van den Bold et al. (2013b) reviewed impact studies which found that HKI's home garden programs have had important positive impacts on women's empowerment (measured in various ways) as well as food security and household nutritional status; Wiggins and Keats (2013) arrive

[12] The website is: http://vgts.avrdc.org/. It is funded by the Swiss Government.

[13] See also http://www.hki.org/reducing-malnutrition/homestead-food-production/ (accessed on April 22, 2014).

at the same conclusion and point out that the benefits have been sustained. A recent unpublished paper raises some questions regarding the equity impacts of HKI's approach, which is based on a social marketing and an innovation diffusion model (from Village Model Farms); it explores alternative approaches to achieve great equity (including empowerment of women) (McIntyre 2012). McDermott et al. (2013) report that HKI has also had to adjust to changing priorities of households, and to consider production of nutritious food for the market as well as for home consumption.

HKI's program in Burkina Faso, funded by USAID, was launched in 2009 and is being implemented in partnership with IFPRI, which is leading a rigorous impact assessment program (HKI 2012; van den Bold et al. 2013b). HKI has adopted an approach, 'Enhanced Homestead Food Production' (EHFP) that uses 'behavior change communication' strategies to support improved nutritional practices for children 3-12 months in age. The research will assess the impact of the program on the prevalence of stunting. It is too early in the program to report results, though HKI (2012) quotes anecdotal evidence for positive impacts. van den Bold et al. (2013a), a product of the IFPRI research, focuses on whether HKI's homestead food production programs improve women's access to and control over productive assets and actually enhance women's human capital. They find that there is evidence that women's control over assets is beginning to change as are people's perceptions and opinions about who can own and control assets. Quantifiable impacts on ownership of assets were statistically significant; qualitatively, informants attributed changes in attitudes toward women owning and controlling land directly to the HKI's EHFP program.

4.3 Action Contra La Faim

'Action Against Hunger' *(Action Contre la Faim,* ACF, http: //www.actioncontrelafaim.org/) is a French NGO that works globally to fight under-nutrition. It is currently scaling up its Health and Nutrition Gardens approach in West Africa as well as Latin America, the Caucasus region and Asia. The West African Health and Nutrition Gardens program combines a traditional home gardens approach, (e.g., access to inputs, training in production, etc.) with several gender empowerment and nutrition education components (behavior change communication on diet, hygiene and child care). ACF implemented a 'Health and Nutrition Gardens' program among 1,265 households in Mali between2007 and 2010. An important element of the program was an attempt to systematically evaluate its impacts. The results were very positive: significant increases in the availability of nutritious vegetables, increased dietary diversity, increased nutritional knowledge, and increased consumption of vitamin A-rich foods by children (from 59% to 99% of children). Based on this success, ACF is expanding its programs and has adopted an explicit impact pathway model as a basis for planning and evaluating its program impacts (McDermott et al. 2013). Concerns about the increased burden of added work on women has led to further modifications and better targeting (Wiggins and Keats 2013).

4.4 Other Home Garden Programs in Africa

There are clearly many NGOs and charities promoting home gardens in Africa. But there are evaluations available for only a few cases. Here we briefly describe two other programs based on information from their own web sites; however, there is no evidence available on their actual impacts. These are typical of programs implemented through international charities.

Super Kitchen Gardens West Africa

Pro-natura International is an organization that is implementing a program in Ghana and Cote d'Ivoire that includes promotion of 'super kitchen gardens'. This is described as a new market garden concept that enables creation of an ecological kitchen garden from a kit that can produce one ton of vegetables per year and feed a family of ten on a 60 m^2 plot. It is an intensive year-round organic cultivation method that uses little water and requires minimal physical effort. The technology makes use of biochar to achieve these results.[14] This information is from the websites of the implementing agency (Pro-Natura International) and its donor (Aire Liquide Foundation); we could not find any further information.

Seeds for Africa School Gardens

This charity focuses on improving children's nutrition through education and provision of seeds, equipment and advice for home and school gardens. For example, in some countries such as Uganda and Sierra Leone it promotes 'breakfast clubs and food gardens' in schools. It appears to receive small grants from the Kellogg Foundation among other sources to support its relatively small programs.[15] Again, we could not find further information.

4.5 Conclusion

There is a substantial literature purporting to evaluate the impacts of home gardens as distinguished from commissioned evaluations of specific home garden programs. These studies examine a variety of types of impacts: on the diets of household members, especially children; on livelihoods; on the health of children; and social impacts, for example, gender empowerment and intra-household equity. This section discusses some of the evidence that is available in published studies.

Impacts of Home Gardens on Diets, Nutrition and Children's Health

Micronutrient malnutrition is a widespread and serious public health issue in many developing countries. A survey of vitamin A, iron and zinc intakes in rural households in Rwanda, Tanzania and Uganda confirmed this observation for those countries. Home gardens are considered to be one type of intervention that could reduce such malnutrition, especially among children (Ecker et al. 2010). Nutrition-sensitive agricultural interventions are therefore receiving increased attention from various donors, including USAID and the Bill and Melinda Gates Foundation. Producing more food by itself is not enough; more evidence is needed on the impact pathways to achieve better nutritional outcomes (Webb 2013). The World Bank also commissioned an analysis of the pathways by which agricultural development and interventions can lead to improved nutrition outcomes (World Bank 2007). Overall, the evidence suggests home garden interventions usually lead to more consumption of nutritious food, but there is little or no evidence on the actual biological health outcomes or on the impact pathways from consumption to physical health

[14] See http://www.fondationairliquide.com/en/projects-supported/micro-initiatives/entrepreneurship/practical-training-programs-in-agro-forestry-and-kitchen-gardens-in-ivory-coast-and-ghana.html; and http://www.pronatura.org/?page_id=17&lang=en (both accessed on April 22, 2014)

[15] See http://blogs.worldwatch.org/nourishingtheplanet/tag/charity/; and http://www.seedsforafrica.org/ (accessed on April 22, 2014)

outcomes, (e.g., Webb 2000, Altman et al. 2009a, b [South Africa]; Musotsi et al. 2008 [Kenya]; Bertie et al. 2004, Girard et al. 2012, Webb 2013, Wiggins and Keats 2013 [comparative literature reviews]). However, there are exceptions: The World Bank (2007) reviewed four case studies in SSA where there were clear positive impacts on nutritional outcomes, though tracing the impact pathway was not easy.

Bertie et al. (2004) carried out a careful study of 30 cases of agricultural interventions to identify the nutrition outcomes (in terms of improved diets). They used the sustainable livelihoods framework to assess the impacts. They found that while most agricultural interventions do not have a discernible impact on nutrition, nearly all home garden projects (11 out of 13) had positive impacts on nutrition, defined in terms of consumption of vegetables and fruit. A key finding was that those interventions that address four or five of the capitals had the greatest impact, and most home garden projects did indeed address multiple capitals. Nutrition education as part of the home garden intervention is especially critical; improving household financial status and gender equity are also very important to achieve sustained improvements in nutrition.

However, Girard et al. (2012), in a follow-up to the Bertie et al. (2004) study, found a somewhat less positive picture. They reviewed 36 articles on 27 unique projects to systematically identify the effects of agricultural interventions aimed at improving household food production on the nutrition and health outcomes of women and children. Most of the cases were in Southeast Asia; only a few were in Africa. Sixteen of the projects promoted home gardens or the improvement of existing home gardens with micronutrient-rich fruits, vegetables and/or tubers. The authors conclude that while most studies do indeed find an increase in consumption of nutritious food by children and women, the quality of the evidence is low. For example, they provide no evidence on whether the quantities of nutritious foods are sufficient to make a real difference, and they do not measure biological outcomes. Further, few studies document the actual impacts on maternal and child health. In other words, few studies examine the entire pathway from consumption to actual measurable health status. They conclude that “the existing evidence base supports the hypothesis that agricultural strategies improve intakes of micronutrient-rich foods by women and young children when nutrition education, gender and nutrition objectives are explicitly stated” (Girard et al. 2012: 219). However, the hypothesis that the improved intake leads to improved health status has not been confirmed, though it does hold promise.

As demonstrated in a recent review by Webb (2013), these findings confirm those that have been emerging over the past decades. This paper reviews the various impact pathways for agricultural interventions to result in measurable improvements in health. (Webb 2013: 12) concludes that “although there remains widespread faith in the potential for investments in agriculture to help improve nutrition and health, the evidence for this remains insubstantial.” Like other studies, this one is very critical of the methodological weaknesses that lead to inconclusive results. Three research gaps are identified: 1) inadequate specification of causal mechanisms and types of impact; 2) incomplete specification of links or impact pathways; and 3) poor understanding of the relative contributions of various elements of food-based strategies to empirically documented impacts and costs. This paper offers excellent advice on designing impact assessments of agricultural interventions including home gardens using impact pathway models.

Wiggins and Keats (2013) add another critical dimension: they note that where the primary goal is to improve nutrition, complementary activities through education and behavior change efforts, health services, and water and sanitation are necessary to obtain the full benefits. They cite a comprehensive CARE program in Bangladesh and a ‘Micro-nutrient and health (MICAH) program’ run by World Vision (Canada) in five countries — Ethiopia, Ghana, Malawi, Senegal and Tanzania — to promote better micro-nutrition and health care (Wiggins and Keats citing

Berti et al. 2010). In both programs, very poor households in poor rural areas were targeted. In both the Bangladesh and MICAH programs, careful evaluations found significant impacts on health and micro-nutrient deficiencies.

The World Bank (2007) identified four elements that contributed to success of gardens for improved nutrition and health: 1) a strong behavior change component; 2) careful consideration of local contexts; 3) partnership building to promote ownership; and 4) a specific focus on women's empowerment. Designing credible evaluation studies remains a challenge, as does identifying how to scale successful programs up and out. Nevertheless, it is clear that "integrating efforts across sectors — in this case food production, care, water and sanitation, and health — paid off" (Wiggins and Keats 2013:31).

Impacts on Equity and Gender Empowerment

Despite the emphasis in many studies on the importance of gender, van den Bold et al. (2013b) is the only study we found that explicitly attempts to measure the impact of home garden improvement programs on women's empowerment. Their systematic review of literature assesses the impacts of three interventions (cash transfer, agricultural including home gardens and micro finance programs) on women's empowerment, nutrition, or both. They note the large number of studies that perceive women's empowerment is a pathway to achieving improved nutrition outcomes. However, they conclude that evidence of the impact of such agricultural interventions as home gardens on women's empowerment is limited, with mixed results. In some cases there is evidence that women's income, control over their income, participation in household decision making and contributions to household income increased; in others there is no such evidence. The evidence on nutrition impacts is also limited except for increase of vitamin A intake (confirming the findings of other studies). The authors attribute the inconclusive results largely to insufficient research and inadequate research design—again, consistent with the conclusions of the other studies reviewed here.

5. ASSESSMENT OF EVIDENCE ON IMPACTS, BENEFITS, COSTS AND SUSTAINABILITY OF LOW-COST DRIP IRRIGATION

The proponents of drip irrigation systems have raised high expectations with their claims that this technology could be a game-changer for smallholders in Asia and Africa, (e.g., Postel et al. 2001). Many claims have been made regarding the capacity of drip irrigation to save water and labor and increase yields, i.e., to increase water productivity and, therefore, also improve incomes and nutrition (see multiple references cited in van der Kooij et al. 2013). Not surprisingly, this has generated a large number of programs to disseminate the technology as well as a growing number of studies evaluating its performance and impacts. In many cases, the studies are focused on the use of drip irrigation by medium and large-scale commercial farmers; we do not address this sector. There is also growing literature on the benefits of individualized low-cost irrigation technologies such as small pumps and drip irrigation for smallholder commercial farmers in SSA, (e.g., Burney and Naylor 2012; Giordano and de Fraiture 2014; Wichelyn 2014).

Our focus is narrower and includes the following: the potential outcomes of the use of low-cost low-head drip irrigation in home gardens for household use or for household use plus some commercial sales. There is no firm distinction between home-use and commercial-use as this technology spreads to smallholders. Performance evaluations of drip irrigation kits have focused on several important dimensions: technical performance, (e.g., water use efficiency, uniformity, and adequacy of water to meet crop water requirements); economic and social performance, (e.g., costs and benefits, profitability, and gender equity); customer satisfaction and sustainability; and overall impacts on livelihoods and well-being. This section is organized in these terms as well, followed by a broader discussion in the concluding subsection. We focus mainly on African cases but also draw on Asian cases where they seem relevant. Appendix 3 provides a summary table which presents basic data on small low-cost drip irrigation kits.

5.1 Technical Performance of Low-cost Drip Irrigation Systems

We found many studies that attempt to assess the technical performance of small low-cost low-head drip irrigation kits in terms of water use efficiency, uniformity of water flow, labor inputs, and productivity. Experimental studies in the laboratory or controlled experiments carried out by the researchers themselves can be distinguished from studies done on farmers' own experiences or in partnership with farmers. Laboratory studies generally rate drip irrigation kit performance highly, but studies done in farmers' fields are more mixed.

In general, experimental studies show that water use efficiency is substantially higher for drip irrigation than surface irrigation, (e.g., Maisiri et al. 2005). Another study found that low-cost drip irrigation with saline groundwater for the cultivation of horticultural crops is a feasible option under conditions of water shortage, especially for tomatoes (Karlberg and Penning de Vries 2004; Karlberg et al. 2007). Ngigi (2008) evaluated low-head drip irrigation kits in Kenya and concluded that they can be used with 0.5-1.5 m water head without compromising emission uniformity. However, Ndegewa and Lesukat (2007) found some differences in the effect of slope, lateral length and water supply head on emitter discharge in field conditions among four low-cost irrigation tapes (Chapin, Dream, T-tape, and Typhoon 25) available in Kenya. In Mali, Coulibaly and Diallo (2012) found problems with the uniformity of the 'Horticulture Easy Drip Kits' (100 m^2) and concluded they are not yet ready to be recommended to small farmers. Kaluli et al. (2012) carried out a randomized experiment comparing rainwater harvesting to drip irrigation in Kenya. The latter maintained an adequate level of soil moisture resulting in better crop performance than rainwater harvesting. Haregeweyen et al. (2011) found that in Ethiopia, the technical performance of family drip kits was mixed in the field (in terms of uniformity and adequacy) – but this was not the main reason for their limited adoption.

Maisiri et al. (2005) compared surface and drip irrigation on nine farms in Zimbabwe. While confirming water savings of more than 50% by using drip irrigation, they found little difference in yield; use of fertilizer was a more significant influence on yields. They also found that low-cost drip kits did not save labor when water had to be manually lifted into the drum; and overall surface irrigation systems gave higher returns per variable costs. On the other hand, Fandika et al. (2012), in a study in Malawi of the performance of bucket drip irrigation systems combined with treadle pumps, found that the system reduced labor and water use by 25% and that they showed uniform application depth and wetted area. Yields were significantly higher, especially for tomatoes.

Studies of low-cost low-head iDE drip irrigation kits for fruits and vegetables in Southeast Asian vegetable-agroforestry gardens have had similar mixed results. In the Philippines, drip-irrigated yields are higher than rainfed yields (hardly surprising) and its use is financially attractive (Ella et al. 2012). In Indonesia, use of drip irrigation during the wet season did not affect yields (Susila et al. 2012); while in Vietnam, income from vegetable cultivation in farmers' home gardens increased only slightly with drip irrigation compared to their current irrigation practice, despite greater water and labor productivity (Pham Hong Duc Phuo et al. 2011).

van der Kooij et al. (2013) systematically analyzed 49 studies of the technical performance of drip irrigation. They found that while most studies define the problem addressed in terms of overcoming water scarcity, how they measure performance in terms of water use efficiency and water productivity varies enormously: there is no uniform set of criteria in use. Remarkably, most reviewed studies were carried out at research institutes; only three of the studies reviewed were on farmers' fields and as used by farmers (including Maisiri et al. 2005 cited above). They conclude that most studies are overly focused on technical performance, rather than the benefits in particular contexts; and most important, the evidence for the water saving potential of drip irrigation is not conclusive. Studies of farmers' use of irrigation show clearly that saving water is rarely an important goal for smallholders. This seems to be a reasonable conclusion.

5.2 Economic and Social Performance of Low-cost Drip Irrigation Systems

Some studies reviewed in the previous section at least partially address the economic performance of low-cost low-head drip irrigation. For example, in Malawi Fandika et al. (2012) found that while treadle pump and bucket and drip irrigation kits do save water and labor, they are profitable only for high-value crops such as tomatoes. In Eritrea, Haile et al. (2003) found that even at US$10.00 for the kit and US$20.00 for the drum, the iDE bucket and drip kit is too expensive for most farmers. Chigerwe et al. (2004) report on results from laboratory tests of four treadle pumps and eight drip kits available in Zimbabwe. They concluded that drip irrigation of gardens of around 1,000 m^2 is viable using a treadle pump and a good-quality drip irrigation kit and cultivating three crops a year. However, the returns on smaller gardens (50-100 m^2) were insufficient to justify using a drip kit with a treadle pump; they recommend irrigation by hand instead.[16]

A similar finding comes from African Market Gardens (AMG) in West Africa. Most studies of the social and economic benefits of smallholder drip irrigation come from West Africa. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners have been testing a horticultural production system for small producers originally developed in Israel. It combines a crop management package with high-quality low-pressure drip irrigation, the African Market Garden (AMG) (Woltering et al. 2011a, b). Similar to the range in size of the iDE drip irrigation kits discussed in section 3.3 above, these kits also come in four sizes, 80 m^2 ('Thrifty'), 500 m^2 ('Commercial'), 'Cluster' (modules of 500 m^2) and 'Community'. The latter two models are for groups of farmers. The Thrifty System is aimed at women who cultivate gardens in the cool dry season. The capital cost of the drip irrigation equipment is 20-25% of the total package. Despite finding that the returns to the Thrifty System are in principle quite good, all 600 of the Thrifty Systems distributed in Niger were abandoned within a year; on the other hand, the larger packages adopted by professional gardeners continued to be used profitably (Woltering et al. 2011a). A related study found that combining the horticultural package with solar-powered drip irrigation systems in northern Benin was profitable and effective in those circumstances (Burney et al. 2010).[17] Based on these optimistic findings, Dittoh et al. (2010) advocate exploring public-private partnerships as a means to promote AMGs in the Sahel.

---

[16] It is often claimed that treadle pumps are an entry level technology, a stepping stone to more sophisticated technologies. This may be the case, but all examples of successful use of treadle pumps are for market garden irrigation, not home gardens for household consumption. See for example: Mangisoni 2008; http://www.kickstart.org/ (accessed on May 26, 2014).

[17] See also http://news.stanford.edu/news/2011/december/solar-drip-irrigation-120511.html (accessed on April 24, 2014).

We did not find any studies that examined the economic benefits, sustainability, and gender or other equity impacts of using low-cost low-head drip irrigation in home gardens, i.e., gardens whose primary purpose is household consumption. Existing studies focus on gardening for the market – even the 'Thrifty' AMG is intended for both market and home use production. Overall, more studies are needed to understand the conditions under which these drip irrigation kits are economical; and studies are needed to understand the gender and equity impacts. Low-cost drip irrigation kits, under certain conditions, ought to be an entry point for enhancing women's well-being and status within the household; but at present there is no evidence on this.

5.3 Customer Satisfaction and Sustainability

This section addresses the question of whether smallholders who use low-cost low-head drip irrigation kits are satisfied with them and continue to use them over time. Sustainable use will, at least in part, be a function of customer satisfaction. Small low-cost drip irrigation kits have been widely distributed in several countries, often by NGOs and charities (in some cases as part of emergency assistance when food supplies are low). Overall, there is strong evidence that households quickly stop using these kits, as seen in Zimbabwe (Rohrbach et al. 2006; Belder et al. 2007; Moyo 2005; Moyo et al. 2006; Merrey et al. 2008); South Africa (Sturdy et al. 2008); Kenya (Kulecho and Weatherhead 2006); Eritrea (Ghebru and Mehari 2005); and Niger (Woltering et al. 2011a).

A survey carried out by ICRISAT in Zimbabwe, where 70,000 small (60% were 100 m^2, most of the others 200 m^2) low-cost low-head drip irrigation kits had been distributed free of cost to poor and vulnerable households through humanitarian relief programs, found that only 16% were in use by year three. A more detailed assessment of a smaller subsample found that most farmers were supplementing the drip irrigation with irrigation using watering cans, as they perceived the drip kits did not apply sufficient water to their crops. Inadequate training and technical support were cited as a major reason for dis-adoption of drip kits. Most people had been growing vegetables before they received their kits. There was no significant difference in the diversity of vegetables grown between users of drip irrigation and those using other methods such as watering cans. The ICRISAT study authors conclude that distributing drip irrigation kits is not an effective strategy for providing humanitarian assistance. Further, water scarcity was not the main impediment to improving productivity and returns to vegetable gardening; making improved seeds and fertilizer available would be a better strategy (Rohrbach et al. 2006; Belder et al. 2007). Other studies in Zimbabwe come to the same conclusion: distribution of drip irrigation kits is not an appropriate relief strategy (Moyo 2005; Moyo et al. 2006; Merrey et al. 2008).

In Eritrea, while farmers recognized the water and labor savings possible with drip irrigation kits, dis-adoption rates were still high. Ghebru and Mehari (2005) studied the adoption and use of the two smallest models --'bucket' (20 m^2) and 'vegetable' (100 m^2) kits -- of the four iDE models available. Most of the kits were sold at a subsidized rate, though some received their kit free with an expectation they would pay if satisfied. A considerable amount of training was also provided, as were brochures in local languages. Of the kits distributed, 52% of the 'bucket kits' and only 23% of the 'vegetable kits' were actually used. The study found the low rate of adoption was largely a function of insufficient knowledge and understanding of the product: "'small-scale' does not necessarily mean 'simple'" (Ghebru and Mehari 2005: 44). Those farmers able to use them profited, but many needed more support in order to make good use of the kits. The authors suggest that farmers' perception of the relatively high risk of adopting the drip irrigation kits was also a factor affecting their adoption.

To summarize, the factors affecting sustained use versus dis-adoption of small drip irrigation kits tend to be similar across countries. They include the following:

- Access to a developed water source; or distance to water source and labor required to carry it;
- Effective technical and institutional support services;
- Access to markets for selling high-value produce;
- Security for the kit;
- Knowledge and skills for use of drip irrigation (previous experience with irrigated agriculture); and
- Distribution as part of a long-term development program versus distribution as part of emergency humanitarian assistance.

These findings suggest that low-cost low-head drip irrigation kits must not be seen as an easy-to-use technology that can be 'parachuted' onto small farmers' fields. Further, if they are at all appropriate, it is where farmers have opportunities to profit from selling their produce – not where production is largely for home use. Their introduction and dissemination needs to be part of a larger development process, as discussed in the next subsection.

5.4 Conclusions

Surprisingly, we found no studies of the overall contribution of small drip irrigation kits to improving livelihoods and well-being of poor rural people. The exception is commercial farmers with good market access. Indeed, iDE and some of the other vendors of these kits see them as enabling small-plot farmers to profit by selling high-value vegetable and fruit crops in markets. iDE has an elaborate model, 'Poverty Reduction through Irrigation and Smallholder Markets' or PRISM (Magistro et al. 2007), that focuses attention on the entire value chain and enables an analysis of the context as a basis for developing business plans through which smallholders can significantly increase their incomes. iDE claims to have had considerable success in Nepal and parts of India, especially where it has combined promotion of this technology with a larger multiple use of water services (MUS) approach (Magistro et al. 2007; Mikhail and Yoder 2008). However, there is no clear evidence that iDE has achieved similar success in SSA. In West Africa, the distribution of drip irrigation kits as part of a public-private partnership value chain-based development strategy to link smallholders to markets has apparently also been quite successful (Abric et al. 2011), though it would be interesting to follow up several years after the introduction of these programs.[18]

Proponents of drip irrigation kits tend to focus on the technology itself, and its capacity to save water or achieve higher productivity per unit of water used, the potential for saving labor, and thereby creating the potential for increasing farm incomes. But a technology by itself has little meaning; technologies are embedded in a larger socio-technical system including values, institutions, discourses and practices (Venot et al. 2014). It is important to understand how actors perceive and use technological hardware is an integral part of the innovation process. The 'drip dream', as Venot et al. (2014) note, tends to be "constructed to fit and reinforce the values and

[18] Venot et al. (2012) documents the experience of a project in Burkina Faso where distribution of iDE's drip irrigation kits as part of a government program is entirely supply-driven with predictable results.

interests of specific actors”, in this case the proponents themselves. The farmers, however, take a different view, i.e., all too often abandoning quickly the technology after obtaining them.

To conclude, there is no evidence to support the notion that low-cost low-head drip irrigation kits are an appropriate technology for enhancing the productivity of home gardens whose primary purpose is household consumption. In fact, the evidence suggests they are not appropriate in this context. They may, however, be appropriate for smallholder commercial farmers under certain circumstances. These include access to a source of water whose volume is limited, (i.e., water is available but scarce); access to well-functioning markets where there is consistent demand for their produce; and good availability of spare parts, technical support and quality inputs such as seeds. Where these conditions are in place, programs to enable women to gain access to the drip irrigation kits accompanied by the other necessary conditions may have useful impacts – but this needs further investigation and pilot testing.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This paper has reviewed some of the literature on home gardens whose primary purpose is production of food and sometimes herbs and spices for home consumption. Home gardens defined in this manner are distinguished from market gardens. However, there is no firm differentiation: some home garden produce may be sold, while some market garden produce is often consumed by the household. Home gardens are an ancient and ubiquitous practice; most rural people have some kind of home garden. Home gardens tend to be characterized by the large diversity of crops grown; they often are effective at recycling nutrients including organic household wastes and grey water; they involve minimal purchased inputs; and they are usually managed by women, often assisted by children. Home gardens do not exist in isolation: they are an integral component of larger agro-ecological, social, economic and cultural systems.

It has been recognized for decades that agricultural growth itself does not necessarily lead to improved nutrition. Therefore, for many years, governments, donors, UN agencies and NGOs have been promoting home gardens to achieve better family nutrition, mostly with positive results. There are now a large number of guidelines and manuals as well as specific programs; we have reviewed some of these in section 2. Home gardens are perceived as potentially important entry points for empowering women as well as enhancing the nutritional and, therefore, the health status of mothers and their children. Studies have shown clearly that the most successful programs promoting home gardens take an integrated approach, involving the health, water supply and sanitation, agricultural and other sectors; they include strong capacity development and training programs related to nutrition and child care as well as gardening; and they place at least some emphasis on empowering women.

Only a few of the NGOs promoting home gardens for household nutrition have either implemented or commissioned impact evaluations. Most charities have either not carried out such evaluations or have failed to publish them. However, there are numerous evaluations of home gardens (as distinguished from specific home garden programs) and their impacts, and several careful reviews of case studies have been published over the past decade. In general, these studies confirm that people in households with productive home gardens do consume more nutritious fruits and vegetables, though most studies do not quantify the amounts consumed. Some studies confirm the positive impacts on the actual health status of children and mothers — but too few do this. Few home garden programs have adopted clear impact pathway models and even fewer studies have been able to trace the impact pathways clearly, from interventions to health outcomes. Nevertheless, it does seem plausible that well-designed home garden interventions do indeed lead to better health outcomes, and there is evidence that most such programs have a sustained impact. There is, however, very little evidence on equity outcomes: Do home gardens offer an effective entry point for empowerment of women? And does such empowerment contribute to healthier children? It seems plausible that the answer is 'yes' to these questions under some conditions, but there is very little specific evidence.

In the arid, semi-arid, and subhumid tropical regions – which include much of rural SSA – water is a critical input to successful home gardening, and very often a critical problem affecting the year-round productivity of gardens. In principle, it is possible to grow vegetables year-round, even in the cold higher altitudes. But a ready source of water is needed during the dry periods to maintain crop growth. Where there is no source of water close to the garden, it is important to capture and store rainwater as well as household grey water. But for poor rural households with little ready cash to invest, what are the cost-effective ways of obtaining and applying water to gardens?

6.2 Gaps in Knowledge of Water Management for Home Gardens

This study has reviewed several water management practices and technologies that are used in home as well as market gardens. Section 3 reviews rainwater harvesting and grey water reuse combined with storage of water in either above-ground or underground tanks; clay pot or 'pitcher' irrigation; and low-head drip irrigation kits. In section 2 we have also reviewed other garden technologies that include an important element of water management: bag or vegetable tower gardens, keyhole gardens, and trench gardens. Advice on how to use the latter set of technologies is included in a number of garden manuals and training curricula reviewed in section 2.

We were unable to find any evidence on the scale of use or the actual costs and benefits, impacts, and sustainability of the following technologies:

- Use of grey water or clay pots for irrigating gardens;
- Bag gardens;
- Keyhole gardens; and
- Trench gardens.

However, there are a few studies of the outcomes of programs promoting rainwater harvesting combined with underground storage tanks, for example in Ethiopia; otherwise this too is a neglected area of research.

There are some studies of the impacts and sustainability of programs promoting low-cost low-head drip irrigation kits. The findings here are clear: the use of good quality drip irrigation kits by smallholders in water-scarce areas cultivating high-value crops for assured markets, where farmers have access to adequate technical support, can be profitable and sustainable. However, the promotion of small low-cost kits to poor households producing for their own use with little access to functioning markets is neither profitable nor sustainable.

There has been very little research on the actual use of these water management technologies in people's gardens, and the actual outcomes in economic terms, sustainability, and gender equity. Put differently, there is a need for more studies on the conditions and implementation strategies that would favor using home garden packages including water management interventions as entry points for achieving sustainable equity, food security and nutrition goals.

6.3 Recommendations for Action Research

Based on the findings of this study, we strongly recommend that the ILSSI partners avoid single-dimensional approaches involving, for example, testing specific technologies such as drip irrigation kits. Such research may produce another postgraduate thesis or published paper but will contribute very little to finding ways to promote more productive and nutritious home gardens. We also recommend that the ILSSI partners avoid making assumptions about the interest in and demand for specific water management or other technologies for home gardens. Instead, we recommend that the ILSSI partners build on current home gardening practices, starting with diagnostic appraisals of actual gardening practices, and moving on to participatory action research focused on evaluating promising water management technologies and testing implementation strategies that empower women. In other words, the ILSSI team should follow a participatory demand-driven approach and avoid supply-driven research.

The first step would be participatory diagnostic appraisals of actual home garden practices: what do people grow and why? What are the roles of women, children, and men in gardening? What is the actual productivity of the gardens? What do people do with their produce, including surpluses, if any? What are their actual water management problems and practices? What are the gardeners' own perceptions of the role of the garden and what do they see as main constraints and problems? If water management is a problem, what kinds of solutions would be of interest to them? We recommend developing and testing a garden water management diagnostic methodology modeled somewhat on the *Participatory Rapid Diagnosis and Action Planning for Irrigated Agricultural Systems* (PRDA) manual (van der Schans and Lempériére 2006). The products of this diagnostic activity would be: 1) the diagnosis of issues that need to be addressed (setting the scene for the action research component); and 2) a handbook and training manual on participatory diagnosis and action planning process for home garden improvement.

Building on the first component, we recommend development and implementation of an action research program with three objectives. The first is testing the acceptability and performance of some of the low-cost technologies reviewed in this paper: rainwater harvesting combined with storage, clay pot irrigation, bag gardens (vegetable towers), and trench gardens. The idea is to find out under what conditions these technologies work best for home gardeners (not only physical but social conditions), and which ones are most interesting to the customers. This would be done through a participatory process. The second objective would be to test implementation strategies for promoting a 'menu' of garden water management practices that are not only effective in terms of adoption, but also have the potential to improve the lives and status of women. The idea is to offer home gardeners a range of choices and facilitate them to decide what they would like to do. Though it would need to be adapted, a possible source for designing this process is the 'mind mobilization' approach pioneered by a South African activist discussed in section 3.1 (DWAF 2007; Denison et al. 2011a-e). The third objective, built into the participatory diagnosis and implementation strategy, is to adapt available training modules and curricula (such as those discussed in section 2) to the specific conditions where the research will be carried out. The outputs will be: 1) field-tested information on the performance and acceptability of specific technologies; 2) field-tested implementation strategies that contribute to women's empowerment; and 3) a field-tested garden water management training module based on the lessons learned that can be used by governments and NGOs promoting home gardens.

The two thrusts – the diagnosis and the action research – are best done in partnership with organizations with broad expertise and experience with promoting home gardens. The water management technologies need to be appropriate to the crops grown and horticultural practices of the specific region where the work is done.

Home gardens play critical roles in enabling many poor rural households meet their food security and nutritional requirements, as well as enabling women to earn extra income. But there are clearly opportunities to increase the productivity of home gardens, the consumption of nutritious food, and the lives of women and children using home garden improvements as the entry point.

REFERENCES

Abebe, T.; Wiersum, K.F.; Bongers, F.; Sterck, F. 2006. Diversity and dynamics in home gardens of Southern Ethiopia. In: *Tropical home gardens: A time-tested example of sustainable agroforestry*, eds., Kumar, B.M.; Nair, P.K.R. pp. 123–142. Dordrecht: Springer Science.

Abebe, T.; Sterck, F.J.; Wiersum, K.F.; Bongers, F. 2013. Diversity, composition and density of trees and shrubs in agroforestry homegardens in Southern Ethiopia. A*groforestry Systems* 87(6): 1283-1293.

Abric, S.M.S.; Augeard, B.; Onimus, F.; Durlin, D.; Ila, A.S.; Gadelle, F. 2011. *Lessons learned in the development of smallholder private irrigation for high value crops in West Africa*. Joint Discussion Paper 4. The World Bank, FAO, IFAD, Practica, and IWMI. Washington DC: The World Bank.

Abu-Zreig, M.M.; Yukuo, A.; Hiroko, I. 2006. The auto-regulative capability of pitcher irrigation system. *Agricultural Water Management* 85: 272-278.

Altman, M.; Hart, T.; Jacobs, P. 2009a. *Food security in Southern Africa*. Pretoria, South Africa: Center for Poverty Employment and Growth, Human Science Research Council. Unpublished report, March 31, 2009.

Altman, M.; Hart, T.G.B.; Jacobs, P.T. 2009b. Household food security status in South Africa. *Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa* 48(4): 345-361.

AVRDC (The World Vegetable Center). n.d. *Vegetables go to school: Improving nutrition by agricultural diversification. Training of Trainers Manual*. Funded by Swiss Development Corporation. Unpublished manuscript.

AVRDC. 2012. 2012 Annual Report. AVRDC publication 13-765. Shanhua, Tainan: The World Vegetable Center (AVRDC).

Bainbridge, D.A. 2001. Buried clay pot irrigation: A little known but very efficient method of irrigation. *Agricultural Water Management* 48: 79-88.

Bainbridge, D.A. 2002. Alternative irrigation systems for arid land restoration. *Ecological Restoration* 20(1): 23-30.

Bainbridge, D.A. 2011. *Buried clay pot irrigation*. Restoration note. Available at www.sustainabilityleader.org (accessed on April 22, 2014).

Bainbridge, D.A. 2012. *Superefficient irrigation with buried clay pots*. From the selected works of David A. Bainbridge, January. Available at http://works.bepress.com/david_a_bainbridge/22 (accessed on April 22, 2014).

Belder, P.; Rohrbach, D.; Twomlow, S.; Senzanje, A. 2007. *Can drip irrigation improve the livelihoods of smallholders? Lessons learned from Zimbabwe*. Global Theme on Agroecosystems Report No. 33. Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 32 pp. Available at http://ejournal.icrisat.org/volume5/aes/aes3.pdf (accessed on April 22, 2014).

Berti, P.R.; Krasevec, J.; FitzGerald, S. 2004. A review of the effectiveness of agriculture interventions in improving nutrition outcomes. *Public Health Nutrition* 7(5): 599-609.

Berti, P.R.; Mildon, A.; Siekmans, K.; Main, B.; MacDonald, C. 2010. An adequacy evaluation of a 10-year, four-country nutrition and health programme. *International Journal of Epidemiology* 2010: 1-17, doi:10.1093/ije/dyp389. Cited in: *Smallholder agriculture's contribution to better nutrition,* Wiggins, S.; Keats, S. (2013). London: Overseas Development Institute.

Bhattacharjee, L.; Phithayaphone, S.; Nandi, B.K. 2006. *Home gardens key to improved nutritional well-being*. Report of Pilot Project TCP/Lao/2902(A), "Promotion of home gardens for improved nutritional well-being." RAP publication 2006/14. Bangkok: Department of Agriculture, Ministry of Agriculture and Forestry, Lao People's Democratic Republic; and the Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific.

Burney, J.; Woltering, L.; Burke, M.; Naylor, R.; Pasternak, D. 2010. Solar-powered drip irrigation enhances food security in the Sudano–Sahel. *PNAS* 107(5): 1848-1853.

Burney, J. A.; Naylor, R.L. 2012. Smallholder irrigation as a poverty alleviation tool in sub-Saharan Africa. *World Development* 40(1): 110-123.

Catacutan, D.C.; Mercado, Jr., A.R.; Chiong-Javier, M.E.' Ella, V.B.; Espaldon, M.V.O.; Rola, A.C.; Palada, M.C.; Duque-Piñon, C.; Saludadez, J.A.; Penaso, A.M.; Nguyen, M.R.; Pailagao, C.T.; Bagares, I.B.; Alibuyog, N.R.; Midmore, D.; Reyes, M.R.; Cajilig, R.; Suthumchai, W.; Kunta, K.; Sombatpanit, S. (eds.). 2012. *Vegetable-agroforestry systems in the Philippines.* Special Publication No. 6b. Beijing, China: World Association of Soil and Water Conservation (WASWAC); Nairobi, Kenya: World Agroforestry Centre (ICRAF). 457p.

CRS (Catholic Relief Services). 2008). *Homestead gardening: A manual for program managers, implementers, and practitioners*. Baltimore, MD: Catholic Relief Services. Available at http://www.crsprogramquality.org/storage/pubs/agenv/Lesotho_homestead_gardening_manual_low.pdf (accessed on April 22, 2014).

Chadha, M.L.; Olouch, M. 2007. Healthy diet gardening kit – for better health and income. *ISHS Acta Horticulturae 752*. International Conference on Indigenous Vegetables and Legumes. Prospectus for Fighting Poverty, Hunger and Malnutrition. Available at http://www.actahort.org/members/showpdf?booknrarnr=752_109 (accessed on April 22, 2014).

Chadha, M.L.; Engle, L.M.; Hughes, J. d'A.; Ledesma, D.R.; Weinberger, K.M. 2011. AVRDC—The World Vegetable Center's approach to malnutrition. Chapter 10 in: *Combating micronutrient deficiencies: Food-based approaches,* eds., Thompson, B.; Amoroso, L. Oxfordshire, UK: Food and Agriculture Organization of the United Nations (FAO) and CABI.

Chigerwe, J.; Manjengwa, N.; van der Zaag, P.; Zhakata, W.; Rockström, J. 2004. Low head drip irrigation kits and treadle pumps for smallholder farmers in Zimbabwe: A technical evaluation based on laboratory tests. *Physics and Chemistry of the Earth*, Parts A/B/C 29(15-18): 1049-1059.

Coulibaly, D.; Diallo, D. 2012. Control of «Horticulture Easy Drip Kit de 100 m²» hydraulic characteristics for micro irrigation in Mali. *International Journal of Engineering Research and Applications (IJERA)* 2(6): 1549-1553.

Crosby, C. 2005. Food from used water: Making the previously impossible happen. *The Water Wheel* (January-February): 10-13.

Daka, A.E. 2006. *Experiences with micro agricultural water management technologies: Zambia.* An input to the Study on Agricultural Water Management Technologies for Small Scale Farmers in Southern Africa: An Inventory and Assessment of Experiences, Good Practices and Costs. Report submitted to IWMI, Southern Africa Regional Office. January 2006. Unpublished.

Dang, T.H.; Du, L.V.; Loan, L.T.; Loi, N.K.; Thanh, N.D.; Phuoc, P.H.D.; Midmore, D.; Catacutan, D.; Palada, M.; Reyes, M.; Cajilig R.; Kunta, K.; Sombatpanit, S.eds. 2011. *Vegetable agroforestry and cashew-cacao systems in Vietnam*. Special Publication No. 6a. Beijing, China: World Association of Soil and Water Conservation (WASWAC); Nairobi, Kenya: World Agroforestry Centre (ICRAF).

Denison, J.; Smulders, H.; Kruger, E.; Houghton, T.; Botha, M. 2011a. *Water harvesting and conservation. Volume 1: Development of a comprehensive learning package for education on the application of water harvesting and conservation.* Report to the Water Research Commission by Umhlaba Consulting Group (Pty) Ltd. WRC Report No. TT 492/11. Available at www.wrc.org.za (accessed on April 22, 2014).

Denison, J.; Smulders, H.; Kruger, E.; Houghton, T.; Botha, M. 2011b. *Water harvesting and conservation. Volume 2 Part 1: Technical manual and farmer handouts*. Report to the Water Research Commission by Umhlaba Consulting Group (Pty) Ltd. WRC Report No. TT 493/11. Available at www.wrc.org.za (accessed on April 22, 2014).

Denison, J.; Smulders, H.; Kruger, E.; Houghton, T.; Botha, M. 2011c. *Water harvesting and conservation*. *Volume 2 Part 2: Facilitation and assessment guide for the technical manual*. Report to the Water Research Commission by Umhlaba Consulting Group (Pty) Ltd. WRC Report No. TT 494/11. Available at www.wrc.org.za (accessed on April 22, 2014).

Denison, J.; Smulders, H.; Kruger, E.; Houghton, T.; Botha, M. 2011d. *Water harvesting and conservation. Volume 2 Part 3: Facilitation manual*. Report to the Water Research Commission by Umhlaba Consulting Group (Pty) Ltd. WRC Report No. TT 495/11. Available at www.wrc.org.za (accessed on April 22, 2014).

Denison, J.; Smulders, H.; Kruger, E.; Houghton, T.; Botha, M. 2011e. *Water harvesting and conservation. Volume 2 Part 4: Facilitation and assessment guide for the facilitation manual*. Report to the Water Research Commission by Umhlaba Consulting Group (Pty) Ltd. WRC Report No. TT 496/11. Available at www.wrc.org.za (accessed on April 22, 2014).

Dittoh, S; Akuriba, M.A.; Issaka, B.Y.; Bhattarai, M. 2010. *Sustainable micro-irrigation systems for poverty alleviation in the Sahel: A case for "micro" public-private partnerships?* Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010. Available at http://ageconsearch.umn.edu/bitstream/97045/2/122.%20Sustainable%20Micro%20Irrigation%20in%20the%20Sahel.pdf (accessed on April 22, 2014).

Drechsel, P.; Dongus, S. 2010. Dynamics and sustainability of urban agriculture: Examples from sub-Saharan Africa. *Sustainable Science* 5: 69-78.

DWAF (Department of Water Affairs and Forestry). 2007. *Programme guidelines for intensive family food production and rainwater harvesting.* March draft. Pretoria: DWAF, South Africa.

Ecker, O.; Weinberger, K.; Qaim, M. 2010. Patterns and determinants of dietary micronutrient deficiencies in rural areas of East Africa. *The African Journal of Agricultural and Resource Economics* 4(2): 175-194.

Ella, V.B.; Reyes, M.R.; Yoder, R.; Olila, N.; Palada, M.; Midmore, D.; Dillaha. T. 2012. Low-cost drip irrigation technology for sustainable vegetable-agroforestry systems. Chapter 7 in: *Vegetable-agroforestry systems in the Philippines,* eds., Catacutan, D.C.; Mercado, Jr., A.R.; Chiong-Javier, M.E.; Ella, V.B.; Espaldon, M.V.O.; Rola, A.C.; Palada, M.C.; Duque-Piñon, C.; Saludadez, J.A.; Penaso, A.M.; Nguyen, M.R.; Pailagao, C.T.; Bagares, I.B.; Alibuyog, N.R.; Midmore, D.; Reyes, M.R.; Cajilig, R.; Suthumchai, W.; Kunta, K.; Sombatpanit, S. Special Publication No. 6b. Beijing, China: World Association of Soil and Water Conservation (WASWAC); Nairobi, Kenya: World Agroforestry Centre (ICRAF). Pp 165-76.

Faber, M.; Laurie, S. 2011. A home gardening approach developed in South Africa to address Vitamin A deficiency. Chapter 9 in: *Combating micronutrient deficiencies: Food-based approaches*, eds., Thompson, B.; Amoroso, L. Oxfordshire, UK: Food and Agriculture Organization of the United Nations (FAO) and CABI.

Fandika, I.R.; Kadyampakeni, D.; Zingore, S. 2012. Performance of bucket drip irrigation powered by treadle pump on tomato and maize/bean production in Malawi. *Irrigation Science* 30: 57-68.

FAO (Food and Agriculture Organization of the United Nations). 2001. *Improving nutrition through home gardening: A training package for preparing field workers in Africa*. Rome: FAO. Available at http://www.fao.org/docrep/003/x3996e/x3996e00.htm (accessed on April 22, 2014).

FAO. 2005. *Setting up and running a school garden: A manual for teachers, parents and communities.* Rome: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/docrep/009/a0218e/a0218e00.HTM (accessed on April 22, 2014).

FAO. 2008. *Nutrition and HIV/AIDS: Keyhole gardens in Lesotho*. Food Security, Nutrition and Livelihoods: Lessons from the field. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/ag/agn/nutrition/docs/FSNL%20Fact%20sheet_Keyhole%20gardens.pdf (accessed on April 22, 2014).

Galhena, D.H.; Freed, R.; Maredia, K.M. 2013. Home gardens: A promising approach to enhance household food security and well-being. *Agriculture and Food Security* 2: 8.

Gallaher, C.M.; Kerr, J.M.; Njenga, M.; Karanja, N.K.; WinklerPrins, A.M.G.A. 2013. Urban agriculture, social capital, and food security in the Kibera slums of Nairobi, Kenya. *Agriculture and Human Values* 30: 389-404.

Ghebru, B.; Mehari, A. 2005. Introducing small-scale irrigation technology in Eritrea: Lessons and experiences. In: *Irrigation development in Eritrea: Potentials and constraints*, eds., Mehari, T.; Ghebru, B. Proceedings of the Workshop of the Association of Eritreans in Agricultural Sciences (AEAS) and the Sustainable Land Management Programme (SLM) Eritrea, August 14-15, 2003, Asmara. Berne, Geographica Bernensia. SLM Eritrea, and ESAPP, Syngenta Foundation for Sustainable Agriculture, and Centre for Development and Environment (CDE), University of Berne, 2005. Available at http://www.syngentafoundation.org/__temp/Irrigation_Development_Eritrea.pdf (accessed on April 22, 2014).

Giordano, M.; de Fraiture, C. 2014. Small private irrigation: Enhancing benefits and managing trade-offs. *Agricultural Water Management* 31: 175-182.

Girard, A.W.; Self, J.L.; McAuliffe, C.; Oludea, O. 2012. The effects of household food production strategies on the health and nutrition outcomes of women and young children: A systematic review. *Paediatric and Perinatal Epidemiology* 26(Suppl. 1): 205-222.

Gockowski, J.; Mbazo'o, J.; Mbah, G.; Moulende, T.F. 2003. African traditional leafy vegetables and the urban and peri-urban poor. *Food Policy* 28: 221-235.

Haile, A.M.; Depeweg, H.; Stillhardt, B. 2003. Small-holder drip technology: Potential and constraints in highlands of Eritrea. *Mountain Research and Development* 23(1): 27-31.

Haileselasie, T.H.; G/hiwot, M.T.; Gebremichael, G.E.; Hiluf, S.A. 2012. Agroforestry practices and biodiversity management in backyards in Hiwane, Hintalo Wejerat of Tigray, Northern Ethiopia. *Asian Journal of Agricultural Sciences* 4(2): 110-116.

Haregeweyn, N.; Gebrekiros, A.; Tsunkeawa, A.; Tsubo, M.; Meshesha, D.; Yazew, E. 2011. Performance assessment and adoption status of family drip irrigation system in Tigray State, Northern Ethiopia. Chapter 3 in: *Water conservation*, ed., Jha, M.K. Croatia: InTech. Available at http://www.intechopen.com/books/water-conservation (accessed on April 22, 2014).

Hart, T.G. 2011. The significance of African vegetables in ensuring food security for South Africa's rural poor. *Agriculture and Human Values* 28: 321-333.

HKI (Helen Keller International)/Asia-Pacific. 2001. *Homestead food production – A strategy to combat malnutrition and poverty.* Jakarta, Indonesia: Helen Keller International.

HKI/Cambodia. 2003. *Handbook for home gardening in Cambodia: The complete manual for vegetable and fruit production*. Phnom Penh, Cambodia: Helen Keller Worldwide.

HKI. 2012. *HKI's enhanced homestead food production for improved food security and nutrition in Burkina Faso*. New York, USA: Helen Keller International.

Hemp, C. 2005. The Chagga Home Gardens – relict areas for endemic Saltatoria Species (*Insecta: Orthoptera*) on Mt. Kilimanjaro. *Biodiversity and Conservation* 125: 203-210.

Hemp, C.; Hemp, A. 2008. *The Chagga homegardens on Kilimanjaro*. IHDP Update 2.

iDE (formerly International Development Enterprises). 2011. *2011 iDE product catalogue*. http://www.ideorg.org/OurTechnologies/GlobalSupply.aspx (accessed on April 22, 2014).

iDE. n.d. Technical manual for IDEal micro irrigation systems. iDE and CPWF. Available at http://www.ideorg.org/OurTechnologies/IDEal_Drip_Technical_Manual.pdf (accessed on April 22, 2014).

IWMI (International Water Management Institute). 2010. *Story of the month*. Available at http://www.cgiar.org/web-archives/www-cgiar-org-monthlystory-may_27_2010-html/ (accessed on April 22, 2014).

Kaluli, J.W.; Nganga, K.; Home, P.G.; Gathenya, J.M.; Muriuki, A.W.; Kihurani, A.W. 2012. Effect of rain water harvesting and drip irrigation on crop performance in an arid and semi-arid environment. *Journal of Agriculture Science and Technology* 14(2): 17-29.

KARI (Kenya Agricultural Research Institute). 2011. *Kari drip irrigation kits*. Brochure. Nairobi: KARI.

Karlberg, L.; Penning de Vries, F.W.T. 2004. Exploring potentials and constraints of low-cost drip irrigation with saline water in sub-Saharan Africa. *Physics and Chemistry of the Earth, Parts A/B/C* 29(15-18): 1035-1042.

Karlberg, L.; Rockström, J.; Annandale, J.G.; Steyn, J.M. 2007. Low-cost drip irrigation—A suitable technology for southern Africa? An example with tomatoes using saline irrigation water. *Agricultural Water Management* 89: 59-70.

Keatinge, J.D.H.; Yang, R.-Y.; Hughes, J. d'A.; Easdown, W.J.; Holmer, R. 2011. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. *Food Security*. 3: 491-501.

Kulecho, K.; Weatherhead, E.K. 2006. Adoption and experience of low-cost drip irrigation in Kenya. *Irrigation and Drainage* 55: 435-444.

Kumar, B.M.; Nair, P.K.R. 2004. The enigma of tropical homegardens. *Agroforestry Systems* 61: 135-152.

Kumar, B.M.; Nair, P.K.R. eds. 2006. *Tropical homegardens: A time-tested example of sustainable agroforestry*. AA Doredrecht, the Netherlands: Springer.

Laker, M.C. 2007. Introduction to the special edition of *Water SA* on indigenous crops, water and human nutrition. *Water SA* 33(3, Special Edition): 311-316.

Lakew Desta, V.C.; Wendam-Ageněhu, A.; Abede, Y. eds. 2005a. *Community based participatory watershed development: A guideline*. Addis Ababa: MoARD, Part 1, January.

Lakew Desta, V.C.; Wendam-Ageňehu, A.; Abede, Y. eds. 2005b. *Community-based participatory watershed development: A guideline*. Addis Ababa: MoARD, Part 2, Annex, January.

Landon-Lane, C. 2011. *Livelihoods grown in gardens*. Diversification booklet 2; 2nd edition. Rome: Rural Infrastructure and Agro-Industries Division, Food and Agriculture Organization of the United Nations. Available at http://www.fao.org/docrep/015/i2463e/i2463e00.pdf (accessed on April 22, 2014).

Laurie, S.M.; Faber, M. 2008. Integrated community-based growth monitoring and vegetable gardens focusing on crops rich in ňcarotene: Project evaluation in a rural community in the Eastern Cape, South Africa. *Journal of the Science of Food and Agriculture* 88(12): 2093-2101.

Magistro, J.; Roberts, M.; Haggblade, S.; Kramer, F.; Polak, P.; Weight, E.; Yoder, R. 2007. A model for pro-poor wealth creation through small-plot irrigation and market linkages. *Irrigation and Drainage* 56: 321-334.

Maisiri, N., A.; Senzanje, J.; Rockstrom, J.; Twomlow, S.J. 2005. On-farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system. *Physics and Chemistry of the Earth* 30: 783-791.

Mangisoni, J.H. 2008. Impact of treadle pump irrigation technology on smallholder poverty and food security in Malawi: A case study of Blantyre and Mchinji Districts. *International Journal of Agricultural Sustainability* 6(4): 1-19.

Maroyi, A. 2009. Traditional homegardens and rural livelihoods in Nhema, Zimbabwe: A sustainable agroforestry system, *International Journal of Sustainable Development & World Ecology* 16(1): 1-8.

Marsh, R. 1998. *Building on traditional gardening to improve household food security*. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/docrep/x0051t/x0051t02.htm (accessed on April 22, 2014).

Mati, B.M. 2005. *Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa.* Colombo, Sri Lanka: International Water Management Institute (IWMI). 92p. (IWMI Working Paper 105).

McDermott, J.; Aït-Aïssa, M.; Morel, J.; Rapando, N. 2013. Agriculture and household nutrition security—development practice and research needs. *Food Security* 5: 667-678.

McIntyre, B. 2012. *Increasing equity outcomes in HKI's household food production program*. Unpublished paper shared by author.

Mergen, F. 1987. Research opportunities to improve the production of homegardens. *Agroforestry Systems* 5: 57-67.

Merrey, D.J.; Sullivan, A.; Mangisoni, J.; Mugabe, F.; Simfukwe, M. 2008. *Evaluation of USAID/OFDA small-scale irrigation programs in Zimbabwe and Zambia 2003-2006: Lessons for future programs*. Report submitted by the Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) to USAID's Office of US Foreign Disaster Assistance, Southern Africa Regional Office (USAID/OFDA/SARO) in fulfillment of Contract 674-O-00-07127-00. Unpublished.

Merrey, D.J.; Gebreselassie, T. 2011. *Promoting improved rainwater and land management in the Blue Nile (Abay) Basin of Ethiopia*. Nile Basin Development Challenge Technical Report No. 1, March 2011. Available at http://cgspace.cgiar.org/handle/10568/3317 (accessed on April 22, 2014).

Mikhail, M.; Yoder, R. 2008. *Multiple-use water service implementation in Nepal and India: Experience and lessons for scale-up*. International Development Enterprises (IDE), the Challenge Program on Water and Food (CPWF), and the International Water Management Institute (IWMI). Available at http://www.ideorg.org/OurStory/IDE_multi_use_water_svcs_in_nepal_india_8mb.pdf (accessed on April 22, 2014).

Mitchell, R.; Hanstad, T. 2004. *Small homegarden plots and sustainable livelihoods for the poor*. Rural Development Institute, USA. LSP Working Paper 11 Access to Natural Resources Sub-Programme. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/docrep/007/j2545e/j2545e00.HTM (accessed on April 22, 2014).

Moyo, R. 2005. *Impact and sustainability of drip irrigation kits, in the semi-arid Lower Mzingwane Catchment, Limpopo Basin, Zimbabwe*. A thesis submitted to the University of Zimbabwe (Faculty of Engineering, Department of Civil Engineering) in partial fulfillment of requirements of Master of Science in Water Resources Engineering and Management. CGIAR Challenge Program on Water and Food, RELMA, and WaterNet.

Moyo, R.; Love, D.; Mul, M.; Mupangwa, W.; Twomlow, S. 2006. Impact and sustainability of low-head drip irrigation kits, in the semi-arid Gwanda and Beitbridge districts, Mzingwane Catchment, Limpopo Basin, Zimbabwe. *Physics and Chemistry of the Earth*, *Parts A/B/C* 885-892.

Musotsi, A.A.; Sigot, A.J.; Onyango, M.O.A. 2008. The role of home gardening in household food security in Butere division of western Kenya. *African journal of Food, Agriculture, Nutrition and Development* 8(4): 375-390.

Nair, P.K.R. 1993. *An introduction to agroforestry*. Dordrecht: Kluwer Academic Publishers, in cooperation with International Centre for Research in Agroforestry (ICRAF). Available at http://www.worldagroforestry.org/units/Library/Books/Book%2032/an%20introduction%20to%20agroforestry/html/index.htm?n=0 (accessed on April 22, 2014).

Ndegewa, G.M.; Lesukat, M. 2007. Evaluation of parameters affecting emitter discharge of some low-head drip irrigation technologies in Kenya. *Journal of Agriculture, Science and Technology* 9(1): 28-43.

Ngigi, S.N. 2003. What is the limit of up-scaling rainwater harvesting in a river basin? *Physics and Chemistry of the Earth* 28: 943-956.

Ngigi, S.N. 2008. Technical evaluation and development of low-head drip irrigation systems in Kenya. *Irrigation and Drainage* 57: 450-462.

Ngigi, S.A.; Savenije, H.H.G.; Thome, J.N.; Rockström, J.; Penning de Vries, F.W.T. 2005. Agro-hydrological evaluation of on-farm rainwater storage systems for supplemental irrigation in Laikipia district, Kenya. *Agricultural Water Management* 73: 21-41.

Niñez, V.K. 1984. *Household gardens: Theoretical considerations on an old survival strategy*. Potatoes in Food Systems Research Series Report No. 1. Available at http://pdf.usaid.gov/pdf_docs/pnabc429.pdf (accessed on April 22, 2014).

Niñez, V. 1987. Household gardens: Theoretical and policy considerations. *Agricultural Systems* 23: 167-186.

Oelofse, A.; van Averbeke, W. eds. 2012. *Nutritional value and water use of African leafy vegetables for improved livelihoods.* Report submitted to the Water Research Commission and Department of Agriculture, Forestry & Fisheries, South Africa. WRC Report No. TT 535/12. Available at www.wrc.org.za (accessed on April 22, 2014).

Ojiewo, C.I.; Tenkouano, A.I.; Oluoch, M.I.; Yang, R. 2010. The role of AVRDC - The World Vegetable Centre in vegetable value chains. *African Journal of Horticultural Science* 3: 1-22.

Oluoch, M.O.; Pichop, G.N.; Silué, D.; Abukutsa-Onyango, M.O.; Diouf, M.; Shackleton, C.M. 2009. Production and harvesting systems for African indigenous vegetables. Chapter 5 in: *African indigenous vegetables in urban agriculture,* eds., Shackleton, C.M.; Pasquini, M.W.; Drescher, A.W. London: Earthscan.

Oniang'o, R.; Grum, M.; Obel-Lawson, E. eds. 2008. *Developing African leafy vegetables for improved nutrition*. Regional workshop, 6-9 December 2005. Nairobi, Kenya: Rural Outreach Program. Available at http://www.bioversityinternational.org/uploads/tx_news/Developing_African_leafy_vegetables_for_improved_nutrition_1513.pdf (accessed on April 22, 2014).

Pachpute, J.S. 2010. A package of water management practices for sustainable growth and improved production of vegetable crop in labor and water scarce sub-Saharan Africa. *Agricultural Water Management* 97: 1251-1268.

Palada, M.; Bhattarai, S.; Wu, D.L.; Roberts, M.; Bhattarai, M.; Kimsan, R.; Midmore, D. 2011. *More crop per drop: Using simple drip irrigation systems for small-scale vegetable production*. AVRDC – The World Vegetable Center, Shanhua, Taiwan. AVRDC Publication No. 09-729. 83p. Available at http://avrdc.org/publications/manuals-crop-guides/#.U4SMhWeYbIU (accessed on April 22, 2014).

Paumgarten, F.; Shackleton, C.; Cocks, M. 2005. Growing of trees in home-gardens by rural households in the Eastern Cape and Limpopo Provinces, South Africa. *International Journal of Sustainable Development & World Ecology* 12: 365-383.

Phocaides, A. 2000. *Technical handbook on pressurized irrigation techniques*. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at ftp://ftp.fao.org/agl/aglw/docs/pressirrig.pdf (accessed on April 22, 2014).

Phocaides, A. 2007. *Technical handbook on pressurized irrigation techniques*. 2nd edition. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/docrep/010/a1336e/a1336e00.htm (accessed on April 22, 2014).

Phuoc, P.H.D.; Du, L.V.; Tuan, T.D.; Ha, D.T. 2011. An assessment of a low-cost drip irrigation system for garden-scale vegetable production in Binh Phuoc Province. In: *Vegetable agroforestry and cashew-cacao systems in Vietnam*, eds., Ha, D.T.; Du, L.V.; Loan, L.T.; Loi, N.K.; Thanh, N.D.; Phuoc, P.H.D.; Midmore, D.; Catacutan, D.; Palada, M.; Reyes, M.; Cajilig, R.; Kunta, K.; Sombatpanit, S. Special Publication No. 6a. Beijing, China: World Association of Soil and Water Conservation (WASWAC); Nairobi, Kenya: World Agroforestry Centre (ICRAF).

Postel, S.; Polak, P.; Gonzales, F.; Keller, J. 2001. Drip irrigation for small farmers. *Water International* 26(1): 3-13.

REACH (Renewed Efforts Against Child Hunger). 2008. *Acting at scale: Intervention guide: Local homestead food production (HFP).* (Renewed Efforts Against Child Hunger and undernutrition; a United Nations knowledge sharing portal). Available at http://www.reachpartnership.org/ (accessed on April 22, 2014).

Rodda, N.; Carden, K.; Armitage, N. 2010. *Sustainable use of greywater in small-scale agriculture and gardens in South Africa.* Technical Report. WRC Report No. 1639/1/10. Pretoria: Water Research Commission of South Africa. Available at www.wrc.org.za (accessed on April 22, 2014).

Rodda, N.; Carden, K.; Armitage, N.; du Plessis, H.M. 2011. Development of guidance for sustainable irrigation use of grey water in gardens and small-scale agriculture in South Africa. *Water SA* 37(5): 727-737. WRC 40-Year Celebration Special Edition 2011. Available at http://www.wrc.org.za/Pages/KH_WaterSA.aspx?dt=5&L0=1&L1=4 (accessed on April 22, 2014).

Rohrbach, D.; Belder, P.; Senzanje, A.; Manzungu, E.; Merrey, D. 2006. *Final report on the contribution of micro irrigation to rural livelihoods in Zimbabwe*. Submitted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to the Food and Agriculture Organization of the United Nations (FAO). Unpublished.

Shackleton, C.M.; Pasquini, M.W.; Drescher, A.W. eds. 2009. *African indigenous vegetables in urban agriculture*. London: Earthscan.

Shah, T.; Keller, J. 2002. Micro-irrigation and the poor: A marketing challenge in smallholder irrigation development. In: *Private irrigation in sub-Saharan Africa: Regional Seminar on Private Sector Participation and Irrigation Expansion in sub-Saharan Africa*, eds., Sally, H.; Abernethy, C.L. Colombo, Sri Lanka: International Water Management Institute (IWMI); Food and Agriculture Organization of the United Nations (FAO) and Technical Centre for Agricultural and Rural Cooperation (CTA). Pp. 165-184.

Share-Net. 2009. *Creative garden design. A Share-Net resource book. Reading-to-learn curriculum materials to support Technology, Natural Sciences and Language learning areas*. Howick, South Africa: Share-Net. Available at http://www.tessafrica.net/files/tessafrica/08_creative_garden_design-all.pdf (accessed on April 22, 2014).

SIANI (Swedish International Agricultural Network Initiative); FOCALI (Forest, Climate and Livelihood Research Network). 2014. *Trees in home gardens: Making the most of an age-old practice to improve food security and nutrition*. Stockholm: Swedish International Agricultural Network Initiative (SIANI); Stockholm: Forest, Climate and Livelihood Research Network (FOCALI); Stockholm: Stockholm Environment Institute (SEI); Stockholm: Centre for Environment and Sustainability. Available at http://www.focali.se/filer/SIANI-Focali-2014-Home-gardens-food-security.pdf (accessed on April 22, 2014).

Sijali, I.V. 2001. *Drip irrigation: Options for smallholder farmers in Eastern and Southern Africa*. RELMA Technical Handbook No. 24. Published by Sida's Regional Land Management Unit.

Sijali, I.; Radiro, M.; Obanyi, S.; Kaburu, F.; Komba, E.; Gacheru, J.; Muriuki, E.; Kahiga, P.; Wanyonyi, A. 2009. *Family garden drip irrigation kits: General manual for eighth and quarter acre drip irrigation kit systems*. Irrigation and Drainage Research Programme publication. For distribution with KARI approved drip irrigation kits. Nairobi: Kenya Agricultural Research Institute (KARI).

Stimie, C.M.; Kruger, E.; de Lange, M.; Crosby, C.T. 2010a. *Agricultural water use in homestead gardening systems. Volume 1: Main report*. WRC Report No: TT 430/09. Available at www.wrc.org.za (accessed on April 22, 2014).

Stimie, C.M.; Kruger, E.; de Lange, M.; Crosby, C.T. 2010b. *Agricultural water use for homestead gardening systems. Volume 2: Resource material for facilitators and food gardeners Part 1: Introduction, Chapters 1-3.* WRC Report No. TT 431/1/09. Available at www.wrc.org.za (accessed on April 22, 2014).

Sturdy, J.D.; Jewitt, G.P.W.; Lorentz, S.A. 2008. Building an understanding of water use innovation adoption processes through farmer-driven experimentation. *Physics and Chemistry of the Earth*, *Parts A/B/C* 33(8-13): 859-872.

Susila, A.D.; Prasetyo, T.; Palada, M.C. 2012. Drip irrigation: Will it increase yield in traditional vegetable production systems? Chapter 8 in: *Vegetable-agroforestry systems in Indonesia*, eds., Susila, A.D.; Purwoko, B.S.; Roshetko, J.M.; Palada, M.C.; Kartika, J.G.; Dahlia, L.; Wijaya, K.; Rahmanulloh, A.; Raimadoya, M.; Koesoemaningtyas, T.; Puspitawati, H.; Prasetyo, T.; Budidarsono, S.; Kurniawan, I.; Reyes, M.; Suthumchai, W.; Kunta; K.; Sombatpanit, S. Special Publication No. 6c. Bangkok, Thailand: World Association of Soil and Water Conservation (WASWAC); Nairobi, Kenya: World Agroforestry Centre (ICRAF).

Tesfaye, T.; Tesfaye, K.; Woldetsadik, K. 2011. Clay pot irrigation for tomato (*Lycopersicon esculentum* Mill) production in the North East semiarid zone of Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 112(1): 11-18.

Turner, R.; Hawkes, C.; Waage, J.; Ferguson, E.; Haseen, F.; Homans, H.; Hussein, J.; Johnston, D.; Marais, D.; McNeill, G.; Shankar, B. 2013. Agriculture for improved nutrition: The current research landscape. *Food and Nutrition Bulletin* 34(4): 369-377.

UNEP (United Nations Environment Programme); SEI (Stockholm Environment Institute). 2009. *Rainwater harvesting: A lifeline for human well-being*. A report prepared for UNEP by Stockholm Environment Institute. Nairobi: United Nations Environment Programme (UNEP); Stockholm Environment Institute (SEI). Available at http://www.unwater.org/downloads/Rainwater_Harvesting_090310b.pdf (accessed on April 22, 2014).

UNICEF (United Nations Children's Fund). n.d. *The UNICEF home gardens handbook: For people promoting mixed gardening in the humid tropics*. New York: United Nations Children's Fund.

van den Bold, M.; Pedehombga, A.; Ouedraogo, M.; Quisumbing, A.R.; Olney, D. 2013a. *Can integrated agriculture-nutrition programs change gender norms on land and asset ownership? Evidence from Burkina Faso*. IFPRI Discussion Paper 01315. Washington, DC: International Food Policy Research Institute (IFPRI).

van den Bold, M.; Quisumbing, A.R.; Gillespie, S. 2013b. *Women's empowerment and nutrition: An evidence review.* IFPRI Discussion Paper 01294. Washington, DC: International Food Policy Research Institute (IFPRI).

van der Kooij, S.; Zwarteveen, M.; Boesveld, H.; Kuper, M. 2013. The efficiency of drip irrigation unpacked. *Agricultural Water Management* 123: 103-110.

van der Schans, M.; Lempérière, P. 2006. *Manual: Participatory rapid diagnosis and action planning for irrigated agricultural systems (PRDA).* Colombo, Sri Lanka: International Water Management Institute (IWMI); Food and Agriculture Organization of the United Nations (FAO) -International Programme for Technology and Research in Irrigation and Drainage (IPTRID).

van Ginkel, M.; Sayer, J.; Sinclair, F.; Aw-Hassan, A.; Bossio, D.; Craufurd, P.; El Mourid, M.; Haddad, N.; Hoisington, D.; Johnson, N.; Velarde, C.L.; Mares, V.; Mude, A.; Nefzaoui, A.; Noble, A.; Rao, K.P.C.; Serraj, R.; Tarawali, S.; Vodouhe, R.; Ortiz, R. 2013. An integrated agro-ecosystem and livelihood systems approach for the poor and vulnerable in dry areas. *Food Security* 5: 751-767.

van Rensburg, W.S.; van Averbeke, J.W.; Slabbert, R.; Faber, M.; van Jaarsveld, P.; van Heerden, I.; Wenhold, F.; Oelofse, A. 2007. African leafy vegetables in South Africa. *Water SA* 33 (3): 317-326. (Special Edition). Available at www.wrc.org.za (accessed on April 22, 2014).

Venot, J-P.; de Fraiture, C.; Kouali, G.N.; Snyder, K. 2012. *Improving the sustainability of impacts of agricultural water management interventions in challenging contexts: Case study from Burkina Faso*. IFAD Grant No: 1073-IWMI. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Venot, J-P.; Zwarteveen, M.; Kuper, M.; Boesveld, H.; Bossenbroek, L.; van der Kooij, S.; Wanvoeke, J.; Benouniche, M.; Errahj, M.; de Fraiture, C.; Verma, S. 2014. Beyond the promises of technology: A review of the discourses and actors who make drip irrigation. *Irrigation and Drainage* 63(2): 186-194.

Water for Food Movement; IWMI (International Water Management Institute). n.d. *Mind mobilization for household food security*. Powerpoint presentation. Unpublished.

WRC (Water Research Commission of South Africa). 2013. Health and nutrition. *Nutritional value and water use of African leafy vegetables for improved livelihoods.* Technical Brief. Pretoria: Water Research Commission. Available at www.wrc.org.za (accessed on April 22, 2014).

Webb, N.L. 2000. Food-gardens and nutrition: Three Southern African case studies. *Journal of Family Ecology and Consumer Sciences* 28: 62-67.

Webb, P. 2013. *Impact Pathways from Agricultural Research to Improved Nutrition and Health: Literature Analysis and Research Priorities*. Rome: Food and Agriculture Organization of the United Nations (FAO); World Health Organization (WHO). Available at http://www.fao.org/fileadmin/user_upload/agn/pdf/Webb_FAO_paper__Webb_June_26_2013_.pdf (accessed on April 22, 2014).

Weinberger, K. 2013. Home and community gardens in Southeast Asia: Potential and opportunities for contributing to nutrition-sensitive food systems. *Food Security* 5: 847-856.

Wenhold, F.A.M.; Faber, M.; van Averbeke, W.; Oelofse, A.; van Jaarsveld, P.; Jansen van Rensburg, W.S.; van Heerden, I.; Slabbert, R. 2007. Linking smallholder agriculture and water to household food security and nutrition. *Water SA* 33(3): 327-336. (Special Edition).

Wichelyn, D. 2014. Introduction. Investing in small, private irrigation to increase production and enhance livelihoods. *Agricultural Water Management* 131: 163-166.

Wiggins, S.; Keats, S. 2013. *Smallholder agriculture's contribution to better nutrition.* London: Overseas Development Institute. Available at http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8283.pdf (accessed on April 22, 2014).

Woltering, L.; Ibrahim, A.; Pasternak, D.; Ndjeunga, J. 2011a. The African Market Garden: The development of a low-pressure drip irrigation system for smallholders in the Sudano Sahel. *Irrigation and Drainage* 60: 613-621.

Woltering, L.; Ibrahim, A.; Pasternak, D.; Ndjeunga, J. 2011b. The economics of low pressure drip irrigation and hand watering for vegetable production in the Sahel. *Agricultural Water Management* 99: 67-73.

World Bank. 2002. *The contribution of indigenous vegetables to household food security.* IK Notes No. 44. Available at http://www.worldbank.org/afr/ik/iknt44.pdf (accessed on April 22, 2014).

World Bank. 2007. *From agriculture to nutrition: Pathways, synergies and outcomes*. Washington, DC: The Agriculture and Rural Development Department, the World Bank. Available at http://siteresources.worldbank.org/INTARD/825826-1111134598204/21608903/January2008Final.pdf (accessed on April 22, 2014).

Zemede, A.; Ayele, N. 1995. Home-gardens in Ethiopia: Characteristics and plant diversity. *Sinet (an Ethiopian Journal of Science)* 18(2): 235-266.

APPENDIX 1. REVIEW OF AVAILABLE INFORMATION ON DRIP IRRIGATION KIT MANUFACTURERS AND SUPPLIERS

There are many suppliers of drip irrigation kits globally and in Africa. This section briefly reviews the most important of these, giving their websites for further follow up. The main focus is on suppliers of low-cost affordable drip irrigation kits. We first discuss commercial suppliers, and then nonprofit, (i.e., NGO) suppliers. This is by no means a comprehensive list of suppliers; and there is no intent here to make comparisons or otherwise endorse any particular firm or organization.

Commercial Manufacturers and Suppliers of Drip Irrigation Kits

Some of the large international commercial suppliers of drip irrigation equipment also sell small low-head drip irrigation kits aimed at smallholder farmers. All url links were accessed on April 26 or 27, 2014.

Jain Irrigation Systems Ltd. (http://www.jains.com) is an Indian firm marketing a wide range of irrigation equipment. Its website has a separate page dedicated to gravity-fed (low-head) 'Jain DripKit', available in six models: 30m², 100m², 250m², 500m², 1,000m² and 2,000m² (http://www.jains.com/irrigation/drip%20kit/drip%20kit.htm). This page offers detailed specifications of its low-head kits. It even offers three pump options: solar, foot and hydraulic ram.

Netafim is an Israeli firm noted for its high-quality irrigation equipment that also sells a wide range of irrigation equipment. The firm does offer lower-cost low-head drip irrigation kits and often partners with NGOs to promote smallholder drip irrigation kits, though this is not obvious from its website. https://www.netafim.com/.

Merchantmen of Britain is an international supplier of a diverse portfolio of equipment and tools for smallholder farmers in Africa (http://www.merchantmenofbritain.co.uk/Default.aspx). It is also a supplier of the 'MOB smallholder drip irrigation kit'. According to its website, this is designed specifically for the smallholder farmer to irrigate small areas of the farm, kitchen garden or back yard; this drip irrigation kit irrigates an area of 30 m². The water reservoir is a 20 liter bucket (not provided with the kit) which is suspended approximately 1.5 m above the seed bed to give the required head—in other words a typical setup.

John Deere Water (http://www.deere.com/en_INT/water/index.html) is a unit of a large American firm providing a wide range of agricultural equipment. John Deere Water offers a large range of drip irrigation products, though there is no evidence on its website that it offers low-cost low-head drip irrigation kits (though it is possible it does).

Driptech has as its mission to make affordable drip irrigation systems available for small farmers in developing countries (http://www.driptech.com/). It is apparently a socially conscious firm based in Silicon Valley and marketing its products in Asia. It has a FtF grant; and both Frank Rijsberman and Paul Polak, founder of iDE, are advisors. It claims its equipment is unique and of high quality.

Sunculture (http://sunculture.com/) is a company based in Nairobi, Kenya which sells the AgroSolar Irrigation Kit -- an entirely solar-powered drip irrigation system. The kit combines solar water pumping technology with high-efficiency drip irrigation. The company claims to be a 'one-stop-shop' for Kenyan farmers, providing a solar water pumping solution, a drip irrigation kit, agronomic services, training, access to capital, and access to markets in rural Kenya. It appears to focus entirely on the Kenyan commercial smallholder market.

Amiran Kenyan Ltd. (http://www.amirankenya.com/) is another Kenyan company that supplies a range of products and services to smallholder commercial farmers. According to its website, this includes the Amiran Farmer's Kit (AFK), designed to meet the needs of a farmer or group of farmers by adapting the components of the Kit to suit the climate, terrain, and agricultural experience of the farmer. The AFK incorporates innovative agricultural technologies including the Family Drip System (FDS), an easy to use gravity-based drip irrigation system; a Farmer's Greenhouse and top quality agro-inputs such as seeds, fertilizers and agro-chemicals. The AFK comes complete with installation, training and an agro-support package that allows Amiran to teach the 'Amiran Farmer' how to grow and then continue to be with the farmer throughout the season to ensure the best results. Like SunCulture, this firm is focused on the Kenyan commercial smallholder sector. (http://www.amirankenya.com/index.php?option=com_content&view=article&id=282&Itemid=133).

Global Easy Water Products (GEWP, http://acumen.org/investment/global-easy-water-products-gewp/) is a for-profit spin-off of iDE-India that designs and sells low-cost drip irrigation systems in India. Acumen (http://acumen.org/our-investments/) is a nonprofit investment firm that among others has invested in GEWP.

Nonprofit Suppliers of Drip Irrigation Kits

These are the major not-for-profit suppliers of drip irrigation kits. All url links were accessed on April 26 or 27, 2014.

iDE, formerly International Development Enterprises (http://www.ideorg.org/), is by far the largest and most prominent of the not-for-profit NGOs promoting small-scale irrigation technologies, including a range of drip irrigation kits. We have discussed its range of kits in section 3.3. It began in India and Nepal promoting treadle pumps but soon expanded its work to include a variety of other low-cost smallholder water management technologies, including drip kits. It has a theory of change (PRISM) based on a market-driven model of development of smallholder irrigated agriculture. It manages programs in Asia and a number of SSA countries, and also sells its products online (http://www.ideorg.org/OurTechnologies/GlobalSupply.aspx).

Chapin Living Waters pioneered the promotion of very low-cost bucket and drip irrigation kits and is still active, though now eclipsed by iDE (http://www.chapinlivingwaters.org/). On its website if offers three types of drip irrigation kits with large discounts for quantity purchases (http://www.chapinlivingwaters.org/Special%20Price%20List%20July%201%202013.pdf); it also produces a regular newsletter.

Backpack Farm Agriculture Program (Kenya) appears to be a nonprofit organization though this is not clear from its website (http://www.backpackfarm.com/). Its mission appears to be to support 'eco-friendly' and even organic smallholder commercial agriculture in East Africa. It has a partnership with John Deere Water. According to its website, the program offers an all-in-one backpack package with all the essential, green agri-tech needed by smallholder farmer to standardize both the quality and quantity of agriculture production during an annual growing season, to mirror semi-commercial rates of production. *Inputs include certified seed, fusion farming program, drip irrigation, safety equipment and more.* Most important, farmers receive hands-on training on how best to use the backpack tools as well as build their core capacity. It is a complete five-phase program ensuring smallholder farmers increase their harvests and improve their qualities of life. Together, it is possible to achieve sustainable linkages in *food production, value chains, credible finance, income generation, social and* ecological domains.

Practical Action (http://practicalaction.org/welcome-to-practical-action) is an international

NGO that uses technology to challenge poverty in developing countries. One of its programs is promoting drip irrigation kits in Zambia (http://practicalaction.org/appeal_drip_irrigation), though it is not clear from its website where it sources the kits.

Healing Hands International (http://www.hhi.org/food/what-why) is a faith-based NGO with head offices in the U.S. that provides training in gardening, drip irrigation and post-harvest processing, and distributes drip kits. They have projects in African and Latin American countries as well.

Arid Lands Information Network (ALIN, http://www.alin.or.ke/) is a Kenya-based International NGO that facilitates information and knowledge exchange to and between extension workers and arid lands communities in Kenya, Uganda and Tanzania. Among other activities, it disseminates information on drip irrigation kits and publishes Baobab Magazine and Joto Afrika. (http://www.alin.or.ke/i/Drip%20Irrigation---%20Grow%20more%20vegetables%20with%20less%20water.

APPENDIX 2. SUMMARY TABLE ON TYPES AND MAIN FEATURES OF KITCHEN GARDEN TECHNOLOGIES AND PROGRAMS

Name-type	Size	Main crops	Location	Proponent	Costs in US dollars	Evaluated?	Main references
Selected home garden technologies							
Vegetable tower (also bag, sack)	Varies; 48 x168 cm gunny sack; 90 kg jute sack; larger as well	Multiple – nutritious vegetables	Examples from Sri Lanka, South Africa, Kenya; widely used globally	IWMI in Sri Lanka; WRC in South Africa	Sri Lanka: $10/ bag Kenya: $0.10 for the bag South Africa: no costs given but it is more elaborate than the Kenya case	Yes - for the technology, and no - for longer term performance or sustainability	Sri Lanka: IWMI 2010 Kenya: Mati 2005 South Africa: Stimie et al. 2010a,b; Crosby 2005; Share-Net 2009 Kibera, Nairobi: Gallaher et al. (2013)
Keyhole garden		Multiple – nutritious vegetables	Multiple; examples from Lesotho but widely used in Africa	Send a Cow; CRS, FAO	Not specified; labor and local materials	Yes - for the technology, and no - for longer term performance or sustainability	CRS 2008; FAO 2008
Trench garden (var. tire garden)		Multiple – nutritious vegetables	Multiple; examples from Lesotho, South Africa	CRS, WRC in South Africa	Not specified; Labor and local materials	Yes - for the technology, and- for longer term performance or sustainability	Stimie et al. 2010a, b; CRS 2008; Share-Net 2009; Denison et al. 2011b

(Continued)

APPENDIX 2. SUMMARY TABLE ON TYPES AND MAIN FEATURES OF KITCHEN GARDEN TECHNOLOGIES AND PROGRAMS (Continued)

Name-type	Size	Main crops	Location	Proponent	Costs in US dollars	Evaluated?	Main references
Healthy diet gardening kits	36 m^2	14-18 different nutritious vegetables, indigenous and exotic	six countries, East Africa	AVRDC	Distributed free	No	Ojeiwo et al. 2010
Enhanced homestead food production (EHFP)—drip irrigated	Not specified —group of women, therefore communal	Multiple nutritious vegetables, tree crops and poultry	Burkina Faso	HKI	Not specified—distributed free? (Bangladesh program cost is around $5/ kit)	Yes - in terms of impacts	HKI 2012; van den Bold et al. 2013a
Health and Nutrition Gardens		Multiple nutritious crops	Mali	Action against Hunger	Not specified	Yes - in terms of impacts	Wiggins and Keats 2013; McDermott et al. 2013

(Continued)

APPENDIX 2. SUMMARY TABLE ON TYPES AND MAIN FEATURES OF KITCHEN GARDEN TECHNOLOGIES AND PROGRAMS (Continued)

Name-type	Size	Main crops	Location	Proponent	Costs in US dollars	Evaluated?	Main references
Selected water management techniques for home gardens except drip irrigation							
RWH and storage	Varies: 20-100 m^3, sometimes more	Multiple	Examples from Kenya, Ethiopia, South Africa, others	iDE is a major proponent and supplier internationally, its catalogue describes various technologies but does not give costs	Kenya: $190/ concrete or brick lined; $300 for 100 m^3 plastic or brick lined pond	Yes - for technology, performance and in Ethiopia for sustainability	Kenya: Mati 2005, Ngigi 2003, 2008 Ethiopia: Lakew Desta et al. 2005a,b South Africa: Dennison et al. 2011a-e iDE 2011
Clay pots/ pitcher (or 'bottle-feeding')	Not applicable	Trees; highly productive plants like tomatoes	Worldwide, but Zambia, Kenya, Tanzania, Ethiopia cases	None	$0.75/pot (Tanzania); $1.00/ pot (Zambia) Ethiopia-not specified	Yes - but not for long-term sustained use	Mati 2005; Bainbridge 2001,2002,2011 and 2012; Tesfaye et al. 2011; Pachpute 2010; Daka 2006

APPENDIX 3. SUMMARY TABLE ON MAIN FEATURES OF HOME GARDEN ('FAMILY') DRIP IRRIGATION KITS[19]

Name-type	Supplier	Size (area)	Location (where deployed)	Crops	Costs in US dollars	Evaluated?	Main references
Family nutrition kit (IDS 20) Eritrea, Asia- 'bucket kit' (See HED below)	iDE	20 m^2	Worldwide; Eritrea study (See Zimbabwe case below)	Multiple-fruits, vegetables	Not specified ($10 in Eritrea, 2003)	Yes - especially in South Asia; in Eritrea (negative), but widely used	iDE n.d.; Website (see Appendix 1); Eritrea: Ghebru and Mehari 2005; Haile et al. 2003; Palada et al. 2011
Vegetable garden kit (IDS 100); Asia- 'drum kit' (See HED below)	iDE	100 m^2	Worldwide	Multiple-fruits, vegetables	Not specified ($20 in Eritrea, 2003)	Widely used; Yes - especially in South Asia	iDE n.d.; Website (see Appendix 1) Eritrea: Ghebru and Mehari 2005; Haile et al. 2003; Maisiri et al. 2005 (Zimbabwe for larger kits) Haregeweyn et al. 2011 (Ethiopia for larger kits)
Horticulture Easy Drip (HED)	ADRC (including iDE kits)		Asia, Mali	Multiple-fruits, vegetables	Not clear; seems to be $100 for 100 m^2 version	Yes - in Mali (negative)	Palada et al. 2011 Mali: Coulibaly and Diallo 2012
Drum kit	KARI	135 m^2	Kenya	Multiple-fruits, vegetables	$105 ($140 with 200 l drum)	Yes - by KARI	KARI 2011
'eight acre systems'	KARI	1/8th acre (450 m^2)	Kenya	multiple-fruits, vegetables	$290 ($410 with 1,000 l drum)	Yes - by KARI	KARI 2011; Sijali et al. 2009

[19] Larger equipment intended only for commercial farmers is not included in this table.

(Continued)

APPENDIX 3. SUMMARY TABLE ON MAIN FEATURES OF HOME GARDEN ('FAMILY') DRIP IRRIGATION KITS (Continued)

Name-type	Supplier	Size (area)	Location (where deployed)	Crops	Costs in US dollars	Evaluated?	Main references
African Market Garden (AMG) – 'Thrifty'	ICRISAT	80 m^2	West Africa esp. Niger	multiple-fruits, vegetables	\$126 for drip and reservoir; \$318 for entire package	Yes - in Niger (negative)	Woltering et al. 2011a,b
African Market Garden (AMG) – 'Commercial'	ICRISAT	500 m^2	West Africa esp. Niger	multiple-fruits, vegetables	\$771 for drip and reservoir; \$1,615 for entire package	Yes - West Africa (positive for experienced commercial farmers)	Woltering et al. 2011a,b
Jain drip kit	Jain	30 m^2 [100-2000 m^2 also]	Worldwide but India focus	Vegetables	Prices not given	No	Website (see Appendix 1) (Offers very detailed technical information)
MOB small holder drip irrigation kit	Merchant-men of Britain	30 m^2 (New range from 1/ 2014: 50 m^2)	Worldwide but Africa focus	Vegetables (200 seedlings)	Prices not given	Yes - by KARI, Kenya and Ministry of Agriculture, Namibia	Website (see Appendix 1) Note: it appears the evaluations refer to the old range; there is less detail on the new range of products
MOB tank kit	Merchant-men of Britain	300 m^2 (New range from 1/ 2014: 200 m^2)	Worldwide but Africa focus	Vegetables ("2000 seedlings")	Prices not given	Yes - by KARI, Kenya and Ministry of Agriculture, Namibia	Website (see Appendix 1) Note: it appears the evaluations refer to the old range; there is less detail on the new range of products

(Continued)

APPENDIX 3. SUMMARY TABLE ON MAIN FEATURES OF HOME GARDEN ('FAMILY') DRIP IRRIGATION KITS (Continued)

Name-type	Supplier	Size (area)	Location (where deployed)	Crops	Costs in US dollars	Evaluated?	Main references
Individual bucket kit	Chapin Living Waters	100 foot drip tape	Worldwide	Vegetables	\$10.00 plus shipping (discount for volume)	Yes - in Kenya early years; not recently	Website (see Appendix 1) (volume discount available) Kenya: Ngigi 2008
Super bucket kit	Chapin Living Waters	10 rows drip tape 10 m long	Worldwide	vegetables	\$27.52 plus shipping (discount for volume)	Yes - in Kenya in early years; not recently	Website (see Appendix 1) (volume discount available) Kenya: Ngigi 2008
Driptech drip irrigation kit	Driptech	200 m of tubing as part of kit	Worldwide	Vegetables	Price not given	No	Website (see Appendix 1)
Zimbabwe (free through relief programs)	Multiple, including iDE	100-200 m^2	Zimbabwe	multiple	Free to farmers	Yes (negative)	Rohrbach et al. 2006; Belder et al. 2007

IWMI Working Papers

162 *Review Paper on 'Garden Kits' in Africa: Lessons Learned and the Potential of Improved Water Management*. Douglas J. Merrey and Simon Langan. 2014.

161 *Extent of Arsenic Contamination and its Impact on the Food Chain and Human Health in the Eastern Ganges Basin: A Review*. N. Rajmohan and S. A. Prathapar. 2014.

160 *Revitalizing Canal Irrigation: Towards Improving Cost Recovery*. Ravinder P. S. Malik, S. A. Prathapar and Madhavi Marwah. 2014.

159 *A Framework to Understand Gender and Structural Vulnerability to Climate Change in the Ganges River Basin: Lessons from Bangladesh, India and Nepal.* Fraser Sugden, Sanjiv de Silva, Floriane Clement, Niki Maskey-Amatya, Vidya Ramesh, Anil Philip and Luna Bharati. 2014.

158 *Review of Literature on Chronic Kidney Disease of Unknown Etiology (CKDu) in Sri Lanka.* Andrew Noble, Priyanie Amerasinghe, Herath Manthrithilake and Sutharsiny Arasalingam. 2014.

157 *Hydrogeology of the Eastern Ganges Basin: An Overview.* N. Rajmohan and S. A. Prathapar. 2013.

156 *Rapid Assessment of Water Availability and Appropriate Technologies for Small-scale Farming: Guidelines for Practitioners*. Andrew Keller, Elizabeth Weight and Stuart Taylor. 2013. (Also available in French)

155 *Manual Well Drilling Investment Opportunity in Ethiopia*. Elizabeth Weight, Robert Yoder and Andrew Keller. 2013. (Also available in French)

154 *Improving the Supply Chain of Motor Pumps to Expand Small-scale Private Irrigation in Zambia*. Willem Colenbrander and Barbara van Koppen. 2012.

153 *Gender Aspects of Small-scale Private Irrigation in Africa.* Barbara van Koppen, Lesley Hope and Willem Colenbrander. 2012.

152 *Investing in Agricultural Water Management to Benefit Smallholder Farmers in Ethiopia. AgWater Solutions Project Country Synthesis Report.* Alexandra E. V. Evans, Meredith Giordano and Terry Clayton (Editors). 2012.

IWMI provides free access to all its publications.
Visit
www.iwmi.org/publications/index.aspx

Postal Address
P O Box 2075
Colombo
Sri Lanka

Location
127 Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Telephone
+94-11-2880000

Fax
+94-11-2786854

E-mail
iwmi@cgiar.org

Website
www.iwmi.org

IWMI is a member of the CGIAR Consortium and leads the:

RESEARCH PROGRAM ON Water, Land and Ecosystems

ISSN: 2012-5763
e-ISSN: 2478-1134
ISBN: 978-92-9090-812-8