AGRICULTURAL OPTIONS

Fundamentals of Agricultural Development

EDITED BY: Timothy N. Motis PhD AND Dawn R. Berkelaar

ECHO®

FUNDAMENTALS OF AGRICULTURAL DEVELOPMENT

Chapter 1 of Agricultural Options for Small-Scale Farmers

Edited by

Dr. Timothy N. Motis and Dawn R. Berkelaar

ECHO, Inc.®
17391 Durrance Road
North Fort Myers, FL 33917

ECHO, Inc.

Our mission: Following Jesus by reducing hunger and improving lives worldwide through partnerships that equip people with agricultural resources and skills.

Our vision: Honoring God by empowering the undernourished with sustainable hunger solutions.

Agricultural Options for Small-Scale Farmers: A Handbook for Those Who Serve Them

Published by ECHO, Inc.®

Printed in the United States of America

ISBN: 978-0-9896740-4-1

To purchase this book or for more information contact:

ECHO
17391 Durrance Road
North Fort Myers, FL 33917
USA

Email: echo@echonet.org

For further resources, including networking with other agricultural and community development practitioners, please visit our website: www.ECHOcommunity.org. ECHO's general information website can be found at: www.echonet.org.

ABOUT THIS BOOK

This publication is Chapter 1 of *Agricultural Options for Small-Scale Farmers*, a book filled with practical options for those working to assist small-holder farmers and urban gardeners in the tropics and subtropics, many of whom struggle to produce enough food to feed their families. How can we help the farmer who must survive on a small parcel of degraded land without water or a means to purchase fertilizer? Information is abundant, but how does one sort through it all to find out what interventions will really make a difference? This is where perspective is so important, and the best way to gain it is to connect with like-minded people who have the benefit of experience.

Networking solutions to hunger is what ECHO is all about. We are a global Christian organization that exists to equip people with resources and skills to improve the lives of the poor. Since 1981, an extensive network of missionaries and development workers in over 180 countries has shared ideas through ECHO Development Notes (*EDN*), a quarterly technical bulletin with information on how to grow food under difficult growing conditions.

The first 51 issues of *EDN* were compiled in a previously published book, *Amaranth to Zai Holes*, referred to hereafter as "*AZ*." *Agricultural Options for Small-Scale Farmers* is a sequel to *AZ*, drawing mostly from content in issues 52-100 of *EDN*. However, as it builds on content featured in *AZ*, the sequel contains what we do consider to be the most effective ideas found in 100 issues of *EDN*. *Agricultural Options for Small-Scale Farmers* also features technical notes written by experienced practitioners on agricultural systems they have implemented in the field and that have been adopted by thousands of farmers.

Foundational concepts, such as the weaving of agriculture and community development, are covered in this publication. It contains insights on research to be undertaken, as well as factors and issues to consider, before investing valuable resources in specific project interventions. Chapters 2 through 8 (subsequent ebooks) build on that perspective, covering practical, project-oriented options grouped under topics that include the restoration of unproductive soils, coping with scarce rainfall and crop pests, underutilized crops for human nutrition, diversification of small farms, seed multiplication and storage, and agriculture-related human health issues.

In compiling the book, every effort was made to update internet URLs, contact information for organizations, and prices of various resources. Please recognize, however, that this kind of information changes over time. As *EDN* articles were written and incorporated into the book, editorial comments by ECHO staff were sometimes necessary to clarify information or point out additional resources. Within any given section of text, these comments appear in brackets and are denoted as an editor comment by the abbreviation, "Ed."

Photos referenced in the text weere treated as numbered figures. Pictures that were self-explanatory and did not require referencing in the text were treated as illustrations and, therefore, not numbered.

To conserve space, the authorship of *EDN* editors (Dawn Berkelaar, Martin Price and Tim Motis) appears in the Table of Contents but not in the main body of the book, unless necessary for clarity. In many cases, *EDN* editors summarized journal articles or comments from ECHO's network. In those instances, the journal article or name(s) of network members) appears in the respective section of the book. Recognizing that the content was written over a 30 year period, titles (e.g., "Dr." or "Ph.D") were based on our knowledge of contributors' current (2012) status.

We hope that this publication will provide helpful perspective and practical project options that, ultimately, will lead to improved livelihoods of smallholder farmers around the world. Please let us know if any particular practice or technique covered within these pages has contributed to your efforts in serving the poor. We also invite you to utilize ECHO's network portal (www.ECHOcommunity.org) as together we work towards solutions to hunger.

AKNOWLEDGEMENTS

Dr. Martin Price, co-founder of ECHO, served as ECHO's CEO over a 25 year period beginning in 1981. During those years, Price served as *EDN* Editor, working alongside ECHO staff to produce much of the *EDN* content featured in this book. Before his retirement in 2008, Price began developing a vision for a sequel to *AZ*. His thoughts served as the starting point for creating *Agricultural Options for Small-Scale Farmers*.

Dawn Berkelaar, a former ECHO intern, joined ECHO staff in 2001 as Assistant *EDN* Editor, working with Martin Price. Since 2008, she has worked with Tim Motis as *EDN* Editor. In writing and editing *EDN*, she has corresponded extensively with ECHO's network of international development workers.

ECHO staff member, Cody Kiefer, edited the text for readability and grammar. Kiefer also assisted with formatting and layout and developed the topical index at the end of the book.

ECHO's team of editors has relied heavily upon insights shared by those who have taken the time to network their ideas and experiences through ECHO. Special thanks to everyone who has written to ECHO, letting us know of your successes and struggles in the field. Your willingness to work with *EDN* editors in summarizing your observations has resulted in a unique, field-oriented perspective to ECHO publications.

We want to recognize several writers who accepted invitations to write key sections based on their experiences in the field: Tom Post on the intertwining of agriculture and community development; Dennis Murnyak on fish farming; Tony Rinaudo on Farmer Managed Natural Regeneration; Peter Cunningham on Farmer Managed Agro-Forestry Systems; Roy Danforth on introducing new fruits and on the concept of tree gardens; Nico Bakker on farmer seed fairs; and Jacob and Alvera Stern on sand dams.

Illustrations, photos, graphs and tables came from several sources. Chapters 1 and 4 feature compositions by Twila Farmer, a skilled illustrator. Elsewhere in the text, we used illustrations drawn by Christi Sobel for use in previous ECHO publications. Many of the authors included their own photos and graphs/tables. Finally, various institutions and individuals granted permission to include drawings, figures, and photos in *EDN* publications and in this book.

Finally, ECHO wishes to acknowledge the Tyndale House Foundation for funding the writing and publishing of *Agricultural Options for Small-Scale Farmers*. The Tyndale House Foundation has also contributed to the translation of this and other ECHO publications. Their financial resources have allowed ECHO to greatly expand its capacity to publish information relevant to those using agriculture to serve those in need.

Abbreviations for units of measure used in the text.

Metric			Standard	
Unit	**Abbreviation**		**Unit**	**Abbreviation**
		Area		
hectare	ha		acre	acre
		Distance		
micrometer	µm		inch	in
millimeter	mm		feet	ft
centimeter	cm		mile	mile
meter	m			
kilometer	km			
		Mass		
grams	g		ounces	oz
kilograms	kg		pounds	lb
tonne (1000 kg)	t		ton (2000 lb)	ton
		Temperature		
degrees Celsius	°C		degrees Fahrenheit	°F
		Volume		
milliliter	mL		teaspoon	tsp
liter	L		tablespoon	Tbsp
			gallon	gal

Rates (slash vs "per"): The slash (/) is used for short expressions (e.g., 50 kg/ha); "per" is used for longer expressions (e.g., 5 t manure per ha) for the sake of clarity.

Dilutions: The abbreviation "ppm" is "parts per million" and "ppb" is "parts per billion"

Time: Increments of time (e.g., minutes, days, months) are not abbreviated; however, they are treated as units of measure. Numbers preceding these units are written as Arabic numerals unless they are the first word(s) of a sentence.

Other commonly used abbreviations.

Unit or Acronym	Abbreviation
Elements	
Nitrogen	N
Phosphorus	P
Potassium	K
Percentage of a fertilizer that is nitrogen, phosphorus and potassium	NPK (8-2-8), describes 8%N, 2%P and 8%K
Institutions	
The World Vegetable Center	AVRDC
Consultative Group on International Agricultural Research	CGIAR
Food and Agriculture Organization	FAO
Non-Governmental Organization	NGO

FUNDAMENTALS OF AGRICULTURAL DEVELOPMENT

The Chapter at a Glance

1.1 DEVELOPMENT PRINCIPLES

1.1.1 WEAVING AGRICULTURAL AND COMMUNITY DEVELOPMENT

By Tom Post, PhD, CRWRC (Christian Reformed World Relief Committee)

Perhaps you are new to development work and are wondering where to begin. Or you might already be actively involved in development work, but are questioning how to set your project priorities. In this section, Tom Post shares insights on the relationship between agricultural and community development. He discusses the importance of community ownership of projects, and outlines some typical stages of agricultural development.

Introduction: Starting at the Genesis

I began my journey in international development with the Peace Corps (Belize) as a biology teacher. I'm thankful to the Lord for enriching my life with varied experiences in the area of agricultural and community development. These experiences have included involvement with: a fishing cooperative and small farm animal projects in Honduras; soil-water conservation and soil restoration efforts with Mixteco, Zapateco and Chol farmers in Mexico; semi-arid zone farmers in Kenya; and farmers in humid, Southeast Asia trying out SRI rice. I have also been blessed with formal education in the area of agricultural development, having studied at the University of Florida and the School of Development Studies (University of East Anglia, UK). As one inclined toward the biological and agricultural side of development, it has taken me a long time to grasp the nature of community development and the huge long-term impact brought about by

practicing its principles. From my own journey, having mainly worked with the Christian Reformed World Relief Committee (CRWRC) in various regions, I consider that the world-view-values, participation, ownership, organizing, and empowerment facets of community development are actually foundational to lasting agricultural impact. At the same time, sound thinking about agricultural and community development, based on dialogue and experimentation with promising ideas from both local farmers and outsiders, can be a huge impetus to further community development.

So, let's start our discussion about agricultural development and community development at the beginning of the Bible. We start here because agriculture has everything to do with the attitudes and relationship that human beings—the image-bearers of God—exercise toward the land they use. We have to creatively weave (principles of both agriculture and community development) because God created us to give Him glory, to love our neighbors and to care for His whole creation. Steven Bouma-Prediger, a faculty member at Hope College, has delved deeply into creation care in his book *For the Beauty of the Earth: A Christian Vision for Creation Care*. Taking his work as a starting point, please consider four Hebrew words from the first two chapters of the Bible:

- *kabash*: subdue
- *rada*: have dominion
- *samar*: to protect
- *abad*: to serve

And, consider how these words are used.

> "So God created human beings in His own image, in the image of God He created them; male and female He created them. God blessed them and said to them, 'Be fruitful and increase in number, fill the earth, and subdue (*kabash*: subdue) it. Rule (*rada*: have dominion) over the fish in the sea and the birds in the sky and every living creature that moves on the ground.'" (Genesis 1:27-28)

> "….and there was no one to work (*abad*: to serve) the ground." (Genesis 2:5)

> "The Lord God took the man and put him in the Garden of Eden to serve (*abad*) and to take care of (*samar*: to protect) it." (Genesis 2:15)

Throughout history, aspects of the fallen creation have seemed to merit the *kabash* by the human beings the Lord established as rulers. For example, there are mosquito-infested swamps that humans have drained to make them safe. There are acidic soils that are so much more productive because human beings have added lime and organic matter. But the command to subdue the earth should be understood in balance with the whole message of the Bible and with those other three Hebrew word commands that God directed toward human beings. It is important to balance our human *kabash* impulses by first remembering the shepherding, merciful ways that the Lord Himself governs us. Jesus described Himself as "the Good Shepherd" (John 10: 7-18), and Psalm 72 (verses 1-7 and 12-17) contains a prayer asking that the king be endowed with justice, the ability to defend the afflicted and to save the children of the needy, and the blessing of seeing the land bring forth abundance. The lack of a servant-like (*abad*) and caring (*samar*) attitude by humans has certainly played a part in the destruction of ecosystems. Often it seems that human beings have gone for the *kabash* effect without enough attention to God-like rule—which is shepherding, just, merciful, caring and protective. However, when the weaving of agricultural and community development principles incorporates teachings, values and practices that arise from the concepts that humans bear the image of God and are given the work of creation care—the tapestry can become transformational.

Weaving proven agricultural principles with those of sound community development

Assumptions

Weaving agricultural principles with those of community development is about just that: working with smallholder farmers for better harvests while also working to build the capacity of their communities to affect the root causes of poverty that have held them back. Behind participatory community development lie the following assumptions:

- Hunger is not simply a food supply problem.
- A major cause of hunger is that people lack the resources to buy food, improve production, organize for land rights, and market their products.

From this perspective, hunger is a justice problem, a community organizing challenge, and a challenge of community visioning for what is possible! The key goals of participatory community development are *ownership* and *empowerment*. Facilitation of community development is a process and an art.

Meanwhile, the realm of agriculture is full of ideas with great potential. Yet I assume that my readers know about many great agricultural ideas that did not succeed, and that they want to learn more about how to involve small farmers to develop ownership of a learning process that will lead to success. In addition to the underlying assumptions of community development, there are parallel assumptions behind principles of agricultural development. A few of those assumptions are:

- There actually is a deficiency of staple foods: the rural and urban poor are net buyers of food; and current prices present an incentive for poor farmers to grow more food for self consumption and sale.
- The price of chemical fertilizer, based on fossil fuels, is likely to remain high and move higher. This creates incentive for intensifying efforts to increase soil fertility via sustainable methods.
- That there is large, untapped potential for resource-poor farmers to increase production of subsistence and cash crops. Many organizations have shown that large increases in production per area of land are feasible via methods accessible by smallholder farmers.

It seems that these assumptions behind community and agricultural development are simultaneously true. In the majority of cases, I think there is both a need for community organizing (to overcome underlying barriers of injustice) and the development of new farming methods (to improve crops and soils in low-cost, sustainable ways).

Sound Agricultural Development Principles

Principle 1: Build the human farm

In so many ways, agricultural development is really about growing people. I think that a people-growing, people-centered focus is so fundamental it should be the first principle of agricultural development. In the Bible we learn that men and women share the image of God. But for human beings mired in poverty, this image is often marred by feelings of inadequacy, fatalism and disempowerment. One of the special joys of agricultural development work is to open up the incredible potentials that the Creator has built inside of people, plants and the rest of his creation. A book entitled *The Human Farm*, by Katie Smith, relates the power of envisioning a people-centered agricultural development philosophy as practiced in Honduras by Elias Sanchez and Milton Flores. The book portrays the people-centered approach as a sound first principle for agricultural development.

“Human farming,” or people-growing, is a way to visualize an agricultural development process that builds on what people already know. It opens up new possibilities via a learning process that helps farmers expand their own understanding and decision-making abilities. The first steps in such a process often

include the use of various participatory appraisal methods to understand the realities that the farmers live under. Part of the genius of these methods is that they place the outsider and the villagers together as learners. In this context, where learning takes place in the village or farm, the villagers know more than the outsiders. So these methods lend themselves to an empowering process that is created in an environment of mutual respect. Group exercises such as sketching out the yearly calendar of agricultural activities, mapping the land use of the villagers, and doing walking transects with the villagers can reveal a lot about when their peak labor times are, what their priorities are, when they make decisions, and what amount and kind of land they work on.

Central to the development and spread of improvements to the local agriculture is the effective training and support of local agricultural change agents. These men or women are often called promoters, animators, or simply, leaders. Typically, they would be trained by an outside development agency in regards to relatively simple improvements that focus on the main problems farmers in their villages face. When trained well, they are empowered to become local anthropologists, experimenters and visionaries. Often they will challenge the staff of the development organization with local knowledge and serve as counterparts. Either together with the outsiders, or on their own with local farmers, they will carry out small-scale, low-risk experiments to evaluate promising approaches. They should be accountable to their own local community development organizations. Therefore, they should be chosen by their own group or organization, based on criteria analyzed and decided upon with the outside agency providing additional training and support. The technical focus of these local promoters should be on a few basic techniques so that they can quickly achieve mastery and high self-confidence (Bunch, 1982).

As we shall see, principles of community development—like those of agricultural development—are also about growing people. Though very complementary to the participatory human farm concept, community development includes a stronger emphasis on organizing people in groups.

Principle 2: Focus on the main challenges farmers face.

Human farming begins with building the capacity of local farmers to solve their own problems. For this to have the energizing force of *immediacy* and *relevance* (Vella, Jane. *Learning to Listen, Learning to Teach: the Power of Dialogue Education in Educating Adults*) the development program needs to focus on the main problems local farmers face, working with them to try a few promising ideas in their own context. Given the multitude of fascinating agricultural development potentials that exist, the temptation is strong to try at least five to ten of the ideas we glean from organizations like ECHO—and to try them as soon as possible! Instead, during the early stages of getting to know the village, consider simply asking farmers:

- “What are the main problems you face in producing enough food and income for your family?”
- “What are the main crops and animals you grow?”

And then enter into dialogue with farmers about the following questions:

- “What solutions can we think of?” (Answers to Question 1 above.)
- “What would be your role in working out the solutions? “ (How? When?)

(Notice that going through these four questions would comprise a community action plan.)

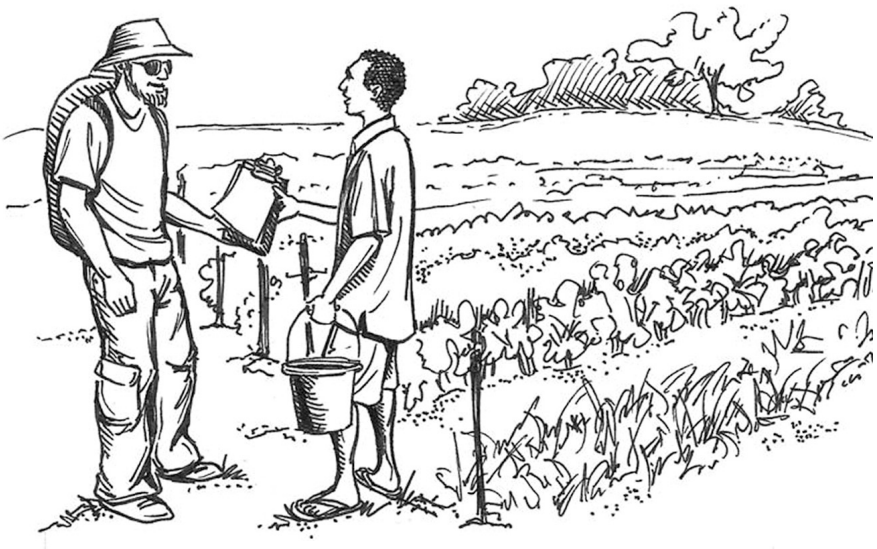
A typical list of main problems could be:

- "Our land is worn out: the yields go down every year and even fertilizer does not seem to give the same effect as before."
- "We have more grass weeds than before."
- "The rains are more erratic; crop failures are more frequent in the last 10 or 20 years."
- "The water in the stream dries up for a longer time now," or, "The water in the wells is receding deeper and deeper."

Typical lists of main crops and animals could be:

- For low altitude tropics: corn, rice, cassava, beans or cowpeas, and sugar cane as a cash crop with cows as the main animal.
- For middle altitude tropics: corn or rice, some type of bean, and coffee as a cash crop with cows as the main animal.
- For high altitude tropics: corn or wheat, perhaps tea or potatoes as a cash crop, with cows, goats, or sheep as the main animal.

The goal of this questioning process is to achieve *focus* and *relevancy*, both of which will contribute to higher levels of ownership. It's the wisdom from *Two Ears of Corn*: start the process of agricultural development *focused* on the main problems farmers face and on the crops or animals that are most important in their livelihood.



After identifying what these main problems are, it is also helpful to use at least a few of the many participatory appraisal tools to understand the reality of the farmers more deeply. The point is to focus on relevant priorities and then go about working with the farmers to try ideas that have potential for solving their chief problems. The ideas addressed should be feasible in terms of cost in labor and cash, and they should not conflict with farmers' overall way of life. We want to start small-scale, low-risk experimentation towards solving the main problems. But where should this begin? In our dialogue with farmers about potential solutions and their role in working them out, we should think together about the following principles.

Principle 3: Due diligence to the soil-water basics (soil-water conservation/restoration)

Very often, the main problems faced by resource-poor farmers are low yields of their primary crops or erratic yields due to unpredictable rainfall. In analyzing these problems more deeply, we will find that often these farmers are working degraded soils, and precious rain water is allowed to cause further erosion. Before we jump to the step of trying improved varieties or new crop species, it is fundamental to work with farmers to find cost-effective methods to slow soil erosion while simultaneously slowing the run-off

of rain water so that more water can permeate into the soil. Attacking these twin problems is of particular urgency in many semi-arid areas (Sanders et al., 1996). Decreasing run-off of topsoil and water involves using mulches, trees and living or dead barriers to make the best use of these valuable resources.

Once erosion and run-off are better controlled, the fertility of the soil needs to be restored so that crop plants can achieve their growth and yield potential. We already know a lot about how to do this. Here are some examples:

- Maximize the production of organic matter. Roland Bunch, after many years of promoting legume cover cropping around the world, recommends: "Huge amounts, in the neighborhood of 10 tons/hectare of fresh weight organic material are needed—so legume cover crops or legume fallows are often the most feasible way." (Bunch, personal communication).
- Protect the soil from the heat of the sun and direct exposure to rain by keeping it covered with mulches, crop residues, etc. This fosters the feeding of the plants and the multiplication of soil micro and macro organisms in and below the mulch cover.
- Use legume cover crops and minimum or zero tillage so that hard pans are avoided and root channels provide aeration and water permeability.
- Maintain biological diversity within the farm and within the soil.
- Use animal manures after storing them with protection from sun and rain.
- Use compost in an effective and targeted way—as both an inoculant of beneficial microorganisms and a source of nutrients.
- Use chemical fertilizer where economically effective, as a complement to organic methods. In many soils, phosphorus is a limiting factor that is most cost-effectively supplied, at least in part, by purchased fertilizer (Palm 1997). Even so, this will only be feasible if farmers are able to realize sufficient cash profit to pay for the phosphorus fertilizer.

Principle 4: Improve the traditional varieties of the most important crops by seed selection, and/or try improved varieties of these crops.

Once erosion and rain run-off have been slowed, and the fertility of the soil has been restored, the potential arises for higher yields of traditional "staff of life" crops. At this stage, it certainly makes economic sense for farmers to invest in selecting the best seed of their traditional crop varieties, and to possibly try improved varieties that are more drought resistant or higher yielding. The self-confidence that farmers gain from seeing improved yields with their traditional crop varieties will often encourage them to try new varieties. These may be new varieties of their main crops, or even entirely new crops if there is a market or a need that is unmet. (Note: ECHO has a good description of Robert Short's method of maize seed selection that I have seen as very effective: www.food-security.info/pdf%20%28English%29/ECHO%20%28English%29/Maize.pdf)

Principle 5: Incorporate market driven-ness when a surplus becomes available.

During the later 1990s I was privileged to participate in an assessment, led by Dr. John Sanders, of the agricultural potential of the semi-arid Horn of Africa. Sanders articulated several of the principles I have shared in this section and has also authored a helpful book, *The Economics of Agricultural Technology in Semi-Arid Sub-Saharan Africa* (1996). He observed that the foundational principles of good soil/water conservation, soil fertility restoration, and varietal improvement are reinforced when farmers are rewarded in the market. He also shared with me a general observation that I have also noted in some countries: demand for poultry meat tends to increase quite rapidly as the urban middle class grows. This creates increased demand for poultry feed and increased reward for farmers whose use of good agricultural practices has increased the yield of feed grains such as maize, sorghum and millet. Working together with farmers to master a set of standards and skills of urban marketing is a developmental process that can reinforce sound agricultural practices and reward farmers with an improved livelihood.

This marketing set includes timeliness, meeting quality and quantity standards, relational trustworthiness and accounting skills.

Some Potential Implications of These Principles for Agricultural Development Practitoners

- Analyze and develop a good understanding of the basic constraints of resource-poor farmers (e.g., soil fertility, water availability).
- Implement a logical development paradigm. Too many times we don't start with the basics, and the basics never get done.
- Train and support local extensionists/promoters, especially in communities where agriculture is the economic backbone. Keep the focus on three or four key technologies that local extensionists can master well, making program support easier.
- Train agricultural development staff to view themselves as adult learners, working with farmers in a participatory and respectful manner. This removes pressure that staff may feel to be the "expert with all the answers", making it easier for them to work together with farmers to search for best-fit solutions.
- Pay more attention to legume fallowing, relay cropping, and cover cropping methods. These practices have high potential for adding large amounts of organic matter. Be aware that this potential can be limited by the complexity of matching legume species to the farming system, climate and soil type.
- Strategically use outside experts and volunteers to foster innovation–but try ideas at a low risk level first!
- Given that fuel prices could very likely be high, depending on the world economy, reinforce nonchemical, non-fuel-dependent agricultural programing emphases.
- Use chemical fertilizer (especially phosphorus) in limited amounts, where needed, to compliment organic fertilizers.
- Where peoples' daily livelihood depends on each day's labor, the well-planned use of food for work can help in construction of agricultural assets (e.g., water catchments, erosion control barriers, etc.).

Participatory Community Development Principles

Definitions

We aim to weave agricultural development within a framework of community development. So what is community development? It can be defined as *a long-term, indigenous, people-centered process developed from participant involvement and enthusiasm that results in transforming, measurable, individual and community change*. The transformational dimension of community development arises when it is based on Christian perspectives put into practice (Myers, 1999). In this way, we can take community development into a deeper dimension: into reflections on Biblical world-view that change how we look at our relationships with ourselves, with fellow community members, with Creation, and with our Creator, God. A good beginning for this transformational track could be to reflect on the Hebrew words used to describe our relationship with Creation and the work God gave to humans, as shared in the introduction.

Transformational community development can utilize the same participation-based, organizational and educational methods as other sound community development strategies. Some of these basic principles that should be noted include:

- Community development is a continuous, self-generating process—not a thing/object to construct or a project to do. The process itself is crucial to the long-term result.
- It is an empowering process that involves people learning and taking responsibility for their own

lives. Community development is owned and managed by the people of the local community.

- At its deepest, it is an integral process that involves people reflecting and working toward their own transformation. Community development is an integrated, holistic process which deals with the whole person: physical, spiritual, and mental.
- Community development is enhanced when accompanied by respectful and knowledgeable community development practitioners. However, the ownership of decision making must lie with the members of the community.

A community development perspective assumes that overcoming poverty requires a people-centered approach that includes the organization of people in ways that enhance their capacity to lead and solve their own problems. When people are not involved in solving their own problems, lasting change is unlikely. I know of a well-intentioned project in which a group of visiting North American farmers saw the needs and irrigation potential of some farmers in southern Africa. When the North Americans returned home they designed simple pumps made from PVC pipe. They had the pumps manufactured in Africa and given out on loans valued at US$50/pump to about 50 farmers. The problem was that even though the pumps effectively increased both the growing season and incomes for some of the farmers, almost none of them paid back the loans. The pumps, then, had to be repossessed by the local program staff. The result was disillusionment for both the farmers and the outside supporters.

Contrast the above example with that of a community development program working with farmers in a high-altitude tropical area, where the program staff and the local village promoters searched and experimented for more than 10 years to find a legume species adapted to their cool climate and mountain soils. Through networking they discovered a non-legume nitrogen-fixing species (a type of alder) that now works along with their composting and soil conservation efforts to greatly improve soil fertility and livelihoods.

Let's take a look at the ownership and leadership differences between the two examples:

- The second program spent far more time organizing village development committees with agricultural sub-committees, which in turn supervised the local farmer promoters. By training the village development committees, the leadership abilities of several men and women were strengthened. As a result, they simultaneously networked to obtain training on soil fertility restoration and tried out the ideas on their own. *This is an example of leadership capacity building that is part of an empowerment process*. The first project relied primarily on a few individuals in North America interacting with a few NGO leaders in the African country. Importantly, it did not include a mechanism (e.g., the organizing of savings groups or other methods) by which local people could pay for the pumps.
- Both ideas, the pumps and the nitrogen-fixing plants, contained elements derived from local and outside knowledge. However, the second program worked closely with the local farmers to *design and try* approaches in small scale trials with little outside money required. This empowered local leaders, as their confidence and problem-solving capacity increased.
- The pace of change in the second program was slower—involving much more local trial and error instead of a solution designed in North America. But, implementation of the second program resulted in much greater ownership by the people. This level of ownership results in local farmers being willing to spend a great amount of their time in the extra work of tree planting, gathering leaves and manure for composting, etc.
- The second program included an intense effort to build the confidence of rather downtrodden local people, to help them see their potential as image bearers of God. It also challenged them to restore the land, respecting it as a gift from God. The North Americans in the first project shared this value for land restoration, but they devoted far less time on it before involving themselves in promoting the pumps.

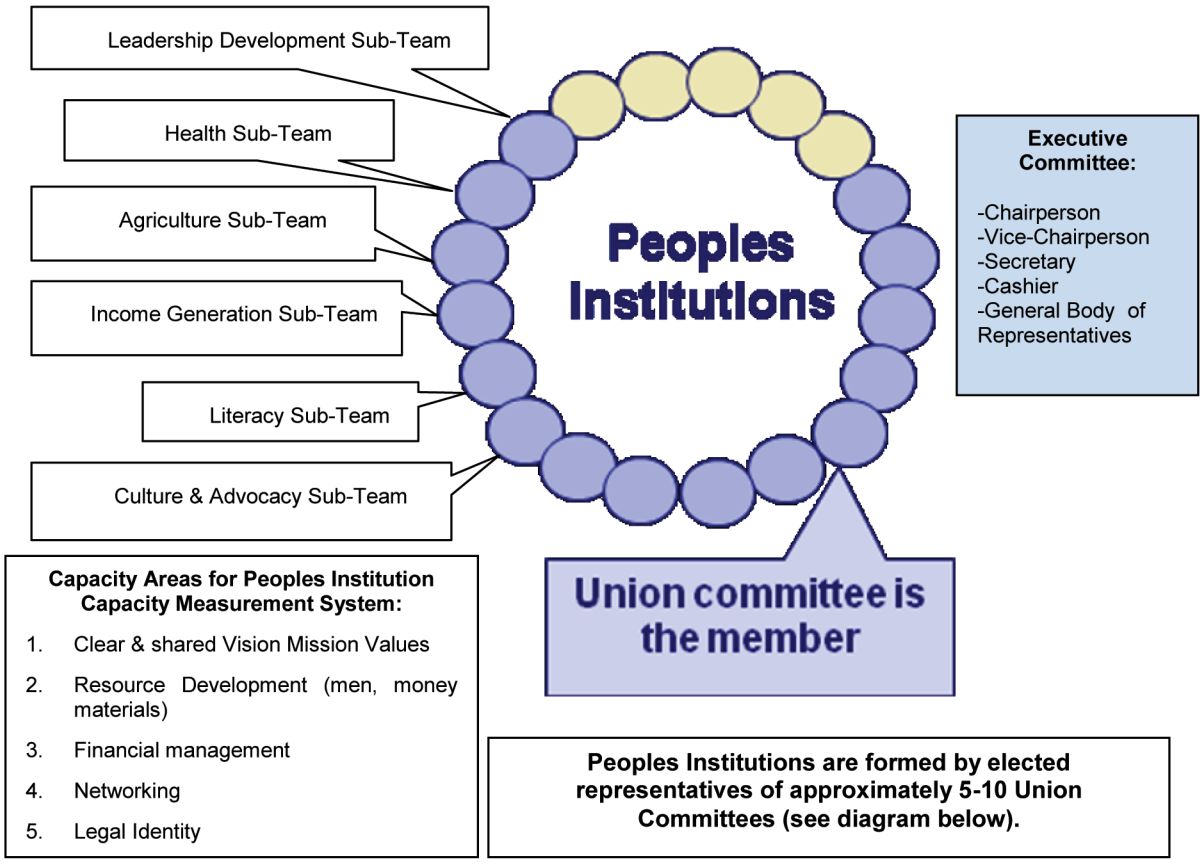
Because some people have more difficulty undertsanding community than agricultural development, I will offer some examples of community development organizational methods that are actually practiced

by the Christian Reformed World Relief Committee (CRWRC) and its partnering agencies (Fig 1.1). I share these examples in hopes of clarifying how agricultural development practices can be woven into a program that emcompases a “human farm” mind-set in community development and organizing.

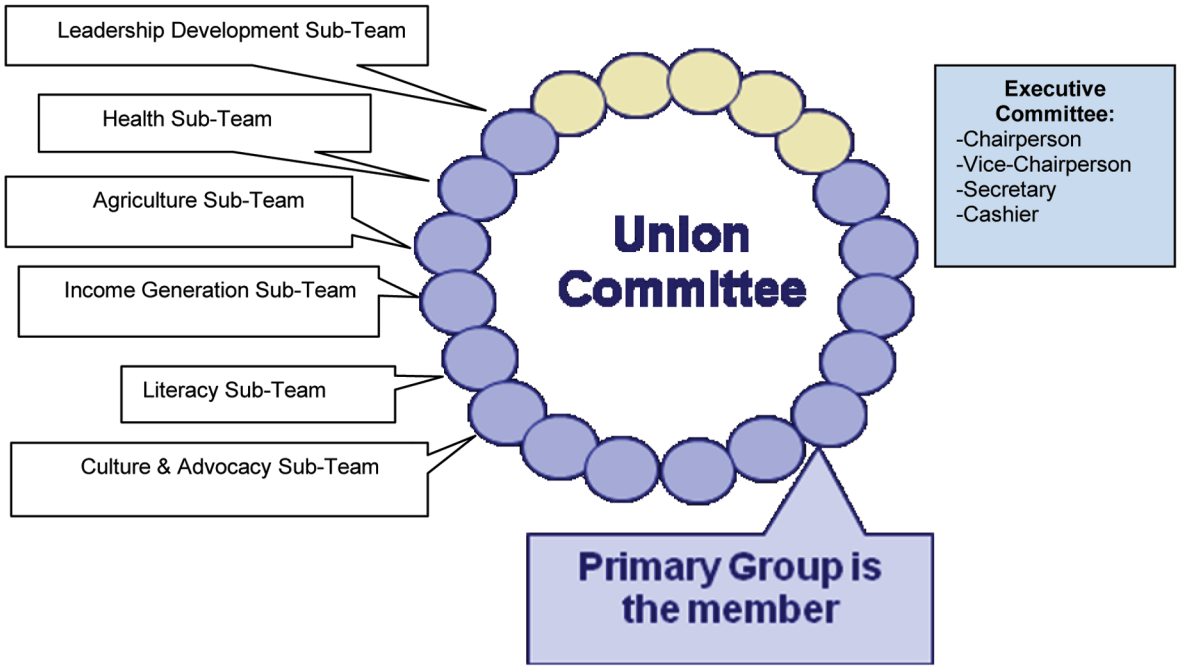
CRWRC-Bangladesh Community Leadership Building Model

This model of community development is a mere sketch of an intricate process that has been developing over the past 15 years. Let me share a few of the highlights. Community development facilitators enter a new community, explain key elements of the vision and methods, invite community members to participate, and then convene a series of pre-group formation exercises that leads to the formation of separate men and women pre-groups. At first, the genders are separated to permit the growth of women’s leadership within a cultural context that has traditionally been very male-dominated. These groups meet weekly, so that members get to know and trust each other. Each member puts a small amount of saved money into the group fund each week to demonstrate ownership and commitment. The fund becomes a group savings/lending account. After three to six months, if members show they are serious about the goal of self-reliance through savings, the group is officially formed and registered. Each member gets a savings passbook and the group gets a bank account. Each group elects its own leaders, and the community development agency trains them in their roles. After this, one of the first program interventions is usually literacy and numeracy training. Soon the members begin lending their own savings funds to each other, usually for small income-generating enterprises such as rearing goats or poultry. Within the primary group, special sub-committees are set up for agriculture, health, literacy, justice issues and leadership.

Figure 1.1: *CRWRC-Promoted Bangladesh Community Leadership Model*



The union committees ensure the functionality of the primary groups, so that they grow and continue to help poor families. Comprised of elected representatives of primary groups, they are closer to the primary groups than the people's institutions.



Union Committees (UC) consist of representatives of the Primary Groups (see diagram below). Thus, they are comprised of a mix of men and women.

The people's institution (PI), made up of representatives of union committees, can take on larger leadership challenges. A PI covers an area one could call a neighborhood or community. This body receives a percentage of the profits from the loans made by the primary groups and is then able to provide larger loans to its members. The PI serves as a unifying and representative force. At this level, men and women work together. For example, a PI can link community health workers and midwives to the regional hospitals, or it can link its agricultural committee leaders to the government agricultural extension offices for training.

CRWRC-Cambodia: Ten steps of community organizing

In Cambodia, CRWRC has borrowed ideas from a wide variety of development practitioners, especially from Mayfield's book (chapters 4 to 6) entitled *Go to the People*. CRWRC-Cambodia now uses a 10 step process:

1. Entry and selection: Community organizers (COs) enter communities, choosing those that show cohesion and readiness to collaborate.
2. Community immersion: The COs live in the communities for extended periods of time, building relationships and trust.
3. Core Group formation: The COs facilitate the formation of "core groups" in each community. These core groups meet with the COs to assess community needs and potentials, and to plan together.
4. CBO formation: The COs and the core group work with the whole community to choose a five-to-seven member development committee, called community-based organization, or CBO.
5. Training and relationship building: The COs work closely with the CBO members to build relation-

ships among them and with the whole community. They also train them in participatory leadership methods. This training and relationship-building continues throughout the next steps.

6. Participatory community research: The CBO members now lead the community research and planning process to identify assets and potentials.
7. Planning: This process, led by CBO members, sets priorities appropriate for the community context.
8. Community resource mobilization: CBO members facilitate the mobilization of community members for training, collaborating on projects, etc.
9. Project implementation: In Cambodia, community research and planning has often shown that improving rice harvests is a high priority—so a common community action process has been to learn and practice System of Rice Intensification (SRI) methods.
10. Graduation/leaving a network of support: Here CRWRC and its partners seek to link CBOs and communities to governmental and NGO agricultural and health services, and to link neighboring CBOs to each other. One of the most promising relationship-building efforts has been in convening meetings between CBO leaders and area police and mayors. This has enabled dialogue on issues that, previously, were difficult to talk about.

Some key community development principles

Here are some principles we can derive from the above descriptions of good community development process:

- To maximize local ownership of the process, right from the start, seek community participation in vision-building as well as in diagnosis and planning.
- Empower the community by training leaders, convening participants in groups, networking with other organizations and resources, etc.
- Build on local resources of leadership, land, water, organizations, etc.
- Start small—within the capacity of local people to manage.

Conclusion

Both the Bangladesh and Cambodia approaches are examples of a step-by-step process that can weave agricultural development into systematic organizing and leadership building. *Ownership* is one of the principle elements in community development, and is one of the main goals in agricultural development as well. *Empowerment* may not be mentioned very often in the context of agricultural development, and it is often talked about in rather general terms in community development. Yet, when an empowering environment for growing people is built very concretely—by organizing local men and women in decision-making groups that are focused on relevant needs, and by training members of these groups to be effective, participatory community leaders and change agents in agriculture (or health, literacy, etc.), so that the leadership and decision making capacity is built and practiced—then empowerment becomes a very tangible, human thing that enhances the image of God in human beings.

Acknowledgements

I would especially like to thank Roland Bunch for his friendship and simple, yet profound writing on people-centered agricultural development. John Sanders' clear prioritization of challenges facing farmers in semi-arid sections of west and east Africa is so helpful.

It has been my privilege to learn from farmers and development colleagues in Mexico (I think of Cristobal Perez in Jerusalen, Chiapas); the Central America countries (I think of Pascual in San Jan Ixcoy, Huehuetenango, Guatemala and Alfonso Vallejos in Patchekan, Belize); the East African countries (I think of "Mwalimus" Dorcas and Casee in Ngaamba, Matchakos District, Kenya). Friends like Moises Colop

in Guatemala, Eugenio Araiza in Mexico, Francis Muthoka in Kenya, and Kohima Daring in Bangladesh have exemplified for me the power of participatory community development facilitators that constantly prioritize the building of peoples' capacity to take leadership, manage money, experiment, and achieve both agricultural and social change.

References with some personal annotations:

Bouma-Prediger, S. 2001. For the Beauty of the Earth: A Christian Vision for Creation Care. Baker Academic, Grand Rapids, Michigan.

Personal note: I have spent some good time reflecting on this book, especially on chapter three. I feel that Bouma-Prediger has done the Christian community a huge service by opening up the nuanced meaning of the words used in the creation account.

Bunch, R. 1982. Two Ears of Corn: A Guide to People-Centered Agricultural Development. World Neighbors, 5116 North Portland, Oklahoma City, Oklahoma. [Ed: Available for download as a pdf file at journeytoforever.org/farm_library/cd3wdbooks.html]

Personal note: Roland has been an inspiration and a good teacher to many. In many ways he has already more effectively said what I have tried to say in this paper.

Hope, A. and S. Timmel. 1987. Training for Transformation: A Handbook for Community Workers. Mambo Press, Harare, P.O. Box 66002. Kopje, Gokomere, P. Bag 9213 Masvingo, Zimbabwe, Africa.

Kohima, D. CRWRC country team leader in Bangladesh, created the diagram on the community organizing structure used there. GPO Box 2164 Dhaka 1000, Bangladesh

Mayfield, J.B. 1985. Go to the People: Releasing the Rural Poor through the People's School System. Kumarian Press, 630 Oakwood Avenue, #119, West Hartford, Connecticut.

Personal note: I am privileged to have seen the expression of Mayfield's vision expressed in Cambodia through the teaching of Toto Ticao, former CRWRC staff person in Cambodia.

Myers, B. 1999. Walking With the Poor: Principles and Practices of Transformational Development. Orbis Books, Maryknoll, New York.

Personal note: Through this book Bryant Myers has had a huge effect on my own understanding of the dimensions of transformational community development. It is, at least for me, a slow-read book that deserves several readings.

Palm, C.A., R.J.K. Myers, and S.M. Nandwa. 1997. Combined Use of Organic and Inorganic Nutrient Sources for Soil Fertility Maintenance and Replenishment. p. 193-217. In: R.J. Buresh, P.A. Sanchez, and F. Calhoun (eds.). Replenishing Soil Fertility in Africa. Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin.

Personal Note: While I was living in Kenya I met Roland Buresh, one of the lead editors of this book. It contains a good overview of scientific research into the challenge of restoring soil fertility. This book is a helpful reminder to development practitioners of the usefulness of careful scientific research for illuminating the nature of the soil fertility challenges we face in agriculture.

Sanders, J.H., Shapiro, B., and Ramaswamy, S. 1996. The Economics of Agricultural Technology in Semi-Arid Sub-Saharan Africa. John Hopkins University Press, 2715 N. Charles St., Baltimore, Maryland.

Personal note: Dr. Sanders encouraged a whole group of Christian development organizations to view the semi-arid lands of East Africa for their assets rather than for their liabilities. He also encouraged us to think through the basic steps that are needed to help the farmers of the semi-arid lands realize the potential that their soils and climatic advantages hold.

Smith, K. 1994. The Human Farm: A Tale of Changing Lives and Changing Lands. Kumarian Press, 1994.

Personal Note: This book elaborates what I experienced by visiting the farm of Elias Sanchez myself and by seeing the ways that my Belizean colleagues were animated when they returned from being with Elias Sanchez in Honduras.

Vella, J. 2002. Learning to Listen, Learning to Teach: the Power of Dialogue Education in Educating Adults. Jossey-Bass, 989 Market St., San Francisco, California.

Personal Note: The practical (seven steps of designing learning interventions) yet profound insights of this book are a treasure. I have found that this book helps make the philosophical vision of Paulo Freire (Pedagogy of the Oppressed) much more accessible to development practitioners.

1.1.2 COMMON MISTAKES IN AGRICULTURAL DEVELOPMENT

Roland Bunch spoke at ECHO's Agricultural Conference in 2003. Below we summarize his talk.

Development is a process of people learning to solve their own problems in a sustainable manner. It means progressing from [solving] one problem to another. Agricultural development is possible in more ways and climates than people often think.

Some common mistakes

Often if you look at a graph of the yield of a particular crop during a specific program's activity, the yield initially rises but then drops again when the program leaves.

One very common mistake is trying to do too many things at once. Successes tend to happen with very simple, limited technologies. Walk beside people, don't run ahead. Farmers cannot take risks and will only pick one or two changes to their usual practices. If each picks a different one, there will be no consensus, and consensus is extremely important in rural communities. It is better to teach one idea to hundreds of people than to teach a hundred ideas to one person. Stick with simple, limited technologies in order to reach a critical mass. You need 35%-40% of people in support of something to change an entire community.

Another common mistake is providing give-aways, donations, and subsidies. In this situation, people feel that development happens *to* them. People become accustomed to receiving, and the donations become crutches that can reduce the multiplier effect. Giving things away changes the development workers' approach, too. They become more likely to begin dictating.

A third common mistake is failing to check the economic feasibility of a particular technology (e.g., compost is uneconomical to use for basic grains).

A key to success

A simple technology is best. Farmers need to be able to adapt it before they will adopt it. If a technology is not changing, it results in—or will result in—low-productivity. There needs to be constant change and constant innovation. Simple technologies should be simple to teach and simple to adapt. Motivate and teach farmers to experiment.

1.1.3 ECONOMICS AND PROFITABILITY, AN EXAMPLE FROM BURKINA FASO

During a trip to Burkina Faso in 2011, Tim Albright (ECHO Chief Operations Officer) and David Erickson (ECHO Chief Organizational Development Officer) were hosted by Robert Sanou on an excursion to visit the farm of Josué Baya. Below are Erickson's notes from that visit.

Ten kilometers off the road from Bobo-Dioulasso to Dédougou, in western Burkina Faso, is a powerful example of a farmer who kept track of his expenses to determine how profitable his gardens actually are. His example is a reminder to anyone working in development that our interventions must be profitable within the small farm context.

Josué Baya's farming practices were revolutionized by what he learned at ECHO's West Africa Networking Forum in September 2010. The knowledge that he developed intrigued and excited him…and he applied it!

- He created a garden near his home, began composting, used plant wastes as ground cover, and did supplemental watering from a nearby well. The results have been astounding: hundreds of papaya; onions; tomatoes; peppers; and more.
- He applied "Foundations for Farming" practices in his field as well, and despite significantly reduced rainfall, his corn crop is spectacular.
- He started growing moringa, harvesting and drying the leaves, and selling moringa powder to new beneficiaries throughout his area.

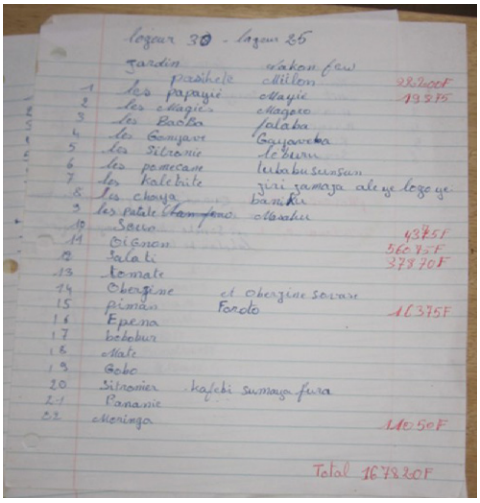


Figure 1.2: *Josué Baya's worksheet with expenses and income.*

At the West Africa Forum, he also learned the importance of tracking his expenditures and revenues (Fig 1.2) and knows "to the penny" exactly where he stands. In just the first few months of the season, his garden has already earned 167,820 cfa (US$379).

Josué Baya's successes have begun to attract attention. Twenty-nine area pastors are individually getting day-long trainings for US$1 each. Other Christian and non-Christian religious groups are asking Pastor Baya to provide training to them as well. A local government administrator has visited Josué and complemented him on his forward-thinking work, reportedly saying that "your work will challenge and change the thinking of a lot of people".

Astounding really! All flowing from one "agricultural change agent" who was sponsored to attend ECHO's West Africa Networking Forum.

1.2 THINK "OUTSIDE THE BOX"

1.2.1 THE GREEN FAMINE

By Tony Rinaudo

Effective research and successful approaches can be developed by simply being observant. For instance, careful observers will notice that, in some situations, there are an abundance of green plants even during times of famine. This has led to some interesting discussion on what constitutes a food crop. Are there crops that could supply food during the leanest of times that aren't being utilized simply because they are not perceived as food crops? Below is a compilation of thoughts on this topic by Tony Rinaudo.

In many marginal farming areas of developing countries, people are going hungry unnecessarily. Often, drought and pests have become scapegoats for the many woes people suffer, but a closer look at the problem may reveal other causes. For example, it is not uncommon for people to rely on crops that are not the most suitable for their region. In 1999, famine affected over 78,000 people in Humbo district (400 km south of Addis Ababa, Ethiopia). Conditions improved but were still serious for 23,000 people in 2002.

The staple crop, maize, had shriveled up in 1999 due to low rainfall and poor distribution of rainfall, yet other vegetation remained green. In fact, World Vision (WV) staff called it a “green famine.”

Drought-stressed areas devoted to maize production in Ethiopia occupy 38%-42% of the total maize-growing area but contribute only about 17% of total maize production. Drought-stressed areas constitute about 46% of all arable land in Ethiopia where 25% of the population live, and maize is one of the most widely grown food crops in these regions (Nigussie, M, et al. Maize Breeding for Drought Stressed Areas Of Ethiopia: A Review. In *25 years of Research Experience in Lowland Crops*. Proceedings of 25th Anniversary of Nazareth Research Center. 22-23 Sept. 1995. Melkassa, Ethiopia). In fact, there are good reasons why people prefer maize. It gives the highest yield per unit area when seasons are good, maize husks provide protection against birds and rain, it is easy to harvest and shell, it does not shatter, it can be harvested over a long period, and people prefer the taste of maize over other foods.

Interestingly, in the small, non-irrigated household gardens, sweet potato, cassava, moringa (an indigenous tree with nutritious edible leaves), paw paw (papaya) and many other edible plants were thriving! When people settled into this part of the hot, semi-arid Rift Valley some 30 years ago, they brought their maize with them. Year after year, the crop has failed, simply because maize is not suitable for the unreliable and erratic rainfall patterns characteristic of the area. Instead of realizing that maize is not a suitable crop for the normal rainfall pattern, blame is placed on “poor” weather for its failure to produce grain.

This concept is not unique to developing countries. Until very recently in Australia, drought was widely considered an unusual ‘natural disaster’ and both farmers and pastoralists routinely expected the government to provide them with compensatory payments to tide them over exceptional drought periods. This view of drought has now been displaced in official policy by the much more realistic idea that drought in Australia is not exceptional, but normal and farmers are being encouraged to work with the environment, not against it (Mercer, D. Whatever Happened to ESD? In *Groundwork* 1 (4), June 1998).

In some more fortunate situations, the problem can be solved by building irrigation systems, or by introducing more hardy varieties of the same crop. Both of these options should certainly be pursued, but they have limits and will not benefit the majority of people for whom there is no irrigation potential, or where the climate is simply too extreme for even the best varieties.

Hunger, in this case, has resulted from reliance on a crop that is unsuitable for the climate, and because people are not accustomed to treating other crops (which do well in the region) as staple foods. Many factors contribute to this lack of interest in, and familiarity with other crops, including: people’s taste preferences, history with the crops, and bad experiences with them. For example, alternative crops that thrive under the same conditions in which maize failed may also have limitations. It is well known that sorghum is one of the most drought resistant crops available, but it appears to be very susceptible to bird damage, and so is not widely grown. Cassava is also extremely drought resistant and suffers no damage from birds, but its tubers do not store well. The same is true of sweet potato.

Ingrained likes and dislikes run deep. Despite recurring food shortages, the community at Humbo has not adopted teaching on how to chip and dry cassava and sweet potato, which would enable these tubers to be stored for long periods. Instead, at harvest time, when a 100 kg sack of sweet potato tubers is worth just US$0.12, tubers are trashed!

There are ways of getting around these problems. In the Makueni district of Kenya where maize crops have repeatedly failed due to drought, farmers are returning to their traditional crops of millet and sorghum. They are finding that when a large enough area of sorghum is planted, bird damage on any one plot is minimized.

In Kaloleni, a coastal district near Mombasa, Kenya, cassava thrives. Yet it is not valued, but rather stigmatized as a poor man’s crop. It is seen as a “famine food”, one that is eaten as a last resort during hunger spells. Farmers sell this abundant food at very low prices in order to buy expensive processed foods (maize and wheat flour, deep-fried potato crisps, etc.).

In collaboration with the Kenyan government's Farm Training Centre in Mombasa, World Vision Kenya is helping people to value cassava by teaching new ways of cooking and processing it. Chapatis (a type of pancake) are a popular food, but are usually made with expensive wheat flour. World Vision facilitators have taught community members how to make cassava flour and mix it in a 1:2 ratio with maize flour for making chapatis. Thus, a monetary saving is made and the end product is actually preferred, being less gluey. Nobody dreamed that cassava could be made into deep-fried chips, which is another popular food. The cassava roots are boiled, the stringy vein is removed and then the root is deep-fried. Mothers are packing these "new" foods in school lunches—and the kids are asking for more! Previously, when children brought boiled cassava to school they were ashamed and afraid of ridicule. Now, children beg their mums to pack extra, so that they can share it with their friends! A type of cassava rissole (fried mash, similar to a hash brown) is also prepared, using mashed cassava roots and leaves (the latter of which happen to be high in protein and vitamins). Simply by changing people's perceptions of cassava, and offering new ways of processing it to produce tastier foods, a whole community is on its way to becoming self-sufficient in food.

A lot of time, money and suffering could be saved in many food-deficient areas. While all avenues should be pursued to alleviate the situation (including, for example, irrigation and crop introduction), we should not overlook what may be staring us in the face. Often, the most suitable crops for the area are already present, but they are undervalued. Small adjustments in the farming method used or a change in the way foods are prepared, coupled with community education, could make a big difference in winning the battle against hunger.

1.2.2 THE VALUE OF WEEDS IN A CORN FIELD

Vieyra-Odilon, L and H. Vibrans. 2001. Weeds as Crops: the Value of Maize Field Weeds in the Valley of Toluca, Mexico. Economic Botany 55 (3): 426-443.

Abstracted by Martin Price, PhD

When I was a child growing up in Ohio, my parents relied heavily on the summer garden to feed our family throughout the year. I noticed that they kept it well weeded until a certain time, and then let the weeds grow. We had all the tomatoes, peppers, potatoes and cucumbers we could eat, even if we had to look through some weeds to find them. Farmers in the Toluca valley in Mexico do the same thing in their corn fields, but not merely to save labor. The weeds themselves are a surprisingly valuable commodity. The authors of this article did an exceptionally extensive study of the practice and economics of growing corn—and of selling or using the weeds.

During one rainy season, they regularly interviewed 24 families in the village and 10 vendors at a regional market about type and quantity of weed use. Also the weed vegetation was surveyed and 49 farmers were interviewed concerning their farming practices and costs. All of the 74 weed species found in corn fields were useful, whether as a forage, a potherb (an edible annual plant), or a medicinal or ornamental plant.

Within the village, 11 species were eaten. The average family consumed 4.5 kg of wild potherbs per month during the rainy season. In the market at Ixtlahuaca, 2,150 kg of 10 species were sold as potherbs, worth US$611. For quantity and gross economic value, plants used as forages were much more important. On average, 1 ha of corn produced a harvest of 1.5 t of green forage, worth about 25% of the gross value of the corn harvest and 55% of its net value. The combination of corn interspersed with forage weeds that can be fed to stabled animals constitutes an interesting integrated farming system. The weeds increase the useful biomass of the field, improve nutrition of the farmers, do not reduce the yield of the main crop (because the fields are kept weed-free during the critical period) and provide erosion control, shade and green manure. The use of weeds in corn fields is facilitated by the fact that one can walk around in a cornfield without damaging the crop, which is not possible in, for example, a wheat or oat field.

Some species of gathered potherbs (mainly *Chenopodium berlandieri* and *Amaranthus hybridus*) arrive

daily at the large wholesale market of Mexico City by the truckload, and are widely available in city supermarkets as well as in the traditional weekly markets in Central Mexico. Other species are marketed on a more local scale. Edible herbs enter trade primarily in the highland and humid tropics, less so in arid regions. Feeding cornfield weeds to domestic animals is a common practice in the whole central highlands of Mexico.

The study area was located in the south-center of Mexico, at about latitude 19°N. There was a summer rainy season, then a dry season. Frosts were frequent at night from November-February.

Corn was sown sometime between early March and mid-May (depending on the variety). Corn was spaced at 3-6 cm planting distance within the row and 80 cm between rows. Farmers cultivate with a cultivator for the first time at the three-leaf stage near the beginning of the rainy season; the second cultivation, with a plow, follows 20-25 days later when the plants are 35-50 cm tall; sometimes there is a third cultivation.

The corn fields are virtually weed free until about June. By that time, the corn forms a dense cover, the critical phase of competition is over and the weeds that subsequently germinate are traditionally left to grow freely. It has been shown repeatedly—and it is common knowledge among farmers—that application of herbicides at this stage does not improve the yield. Even so, today herbicides are sprayed in many areas to make harvesting easier (reduction in spines, stickers, etc.). However, even where herbicides are used, owners of animals will leave an adequate surface untreated to use the weeds later as forage or potherbs. Often weeds are left to grow near the field margins, as they are easier to transport from there.

A look at the economics of growing corn in the study area shows that weeds can be very valuable. The total cost for growing 1 ha of corn is US$367 using a tractor and US$319 using animal traction. The sales price of the harvested corn was US$600-800, based on a yield of 3-4 t/ha and a price of US$200/t (for an average income per ha of US$700). The authors found that the average yield of forage per household was 2661 kg, valued at US$346 (US$111/ha). So on the average, the weeds were worth 33% of the gross value of the corn harvest ($111÷ ($700-$367) = 33%).

For some farmers, the weed harvest was worth far more than half of the maize harvest. In regions with less productive agriculture, or in years with lower maize prices, these percentages could easily be even higher.

If harvesting weeds is so profitable, why do many farmers now use only part of the wild plants that grow in their fields, and spray herbicides on the rest? The authors speculate that (1) there is an upper limit to how many animals can be looked after in periods of high labor demand; (2) costs for feed during the dry season may be too high for most farmers to afford [Ed: numbers of animals on a farm are limited by the amount of feed at the END of the dry season, so an abundance of feed at one season is not a predictor of how many animals the farmer can keep.]; (3) techniques (e.g., hay-making, silaging) for conserving fodder are not known; (4) harvesting weeds is hard physical labor; and (5) cheap external labor is not available on a consistent basis.

1.3 RESEARCH AND EXPERIMENTATION

By the simple act of planting a seed you have, in essence, begun an experiment. You may have high hopes, for instance, that the seeds of a new tomato variety you received in the mail will result in more and better tomatoes than the variety you grew last year. However, you cannot really be sure it will perform well in your location until you grow it out in the field. The risk of trying a new variety might be relatively minor to a missionary working in his or her personal garden. The stakes become much higher when those same seeds or techniques are promoted among local farmers. Credibility can be quickly eroded by encouraging farmers to adapt innovations that have not been tested and end up failing under local conditions. On the other hand, an outsider can be of tremendous service to local farmers by involving them in the process of experimentation. Farmers in developing countries may not be able to take on a great deal of risk in trying new ideas. Nevertheless, research and experimentation—at some level—play an important

role in the life of a farmer. Below are several articles on how research and experimentation can be done within diverse cultural settings and how to conduct your own research.

1.3.1 PARTICIPATORY RURAL APPRAISAL

By Laura Meitzner Yoder, PhD

While we may think of research applying to a specific agricultural crop or practice, there is a more foundational level of research that is important in learning aspects of culture and how to live and work effectively in a new area. The Participatory Rural Appraisal method is an effective approach to gaining this kind of knowledge.

Laura Meitzner Yoder is co-author of ECHO's book Amaranth to Zai Holes (AZ). She has since worked with villagers and universities in Central America and Indonesia.

Below is Laura's response to an initial question from ECHO, "When you began work in a new community, how did you quickly get an overall understanding of the nature and workings of that community to form the base for your future work?"

Introduction

Our first task in a new location is to learn about the lives, needs, and priorities of the people there. Beginning as a learner allows the newcomer to better understand what topics community members feel are most important, so future proposed activities are more likely to fit people's needs and have a better chance of success. Even after years of working in a place, there will still be subjects we wish to understand more fully. But how can we begin to understand villagers' perspectives on ecological niches, cropping patterns, community history, or economic cycles in a region? And can we gather this information in a way that benefits the community, as well as enlarges our own understanding?

Visual techniques

There is no substitute for living in a location for an extended time and spending time talking with people informally in their homes and fields. But certain subjects are difficult to explain or to understand well just by using words. Visual techniques—drawings, diagrams, timelines, or charts made by the villagers themselves—can help people communicate more clearly. Non-literate or shy people are often much more comfortable having something visual to reference during a discussion than interactions involving written materials or direct conversation. Villagers gain confidence as they learn new ways to share their knowledge with each other and with outsiders. People appreciate when we begin by learning from their experience and use their local expertise as a basis for any activities.

Participatory methods

One common technique for learning about a new area is to ask specific questions to local leaders. But while it is important to enlist the knowledge and support of selected individuals, talking only with "local elites"—tribal representatives, religious leaders, and those with special positions such as teachers and village entrepreneurs—can give us a very narrow perspective on life in the community. Talking to people one at a time can also be time-consuming when we want to understand what a large number of people know or feel about a topic. On occasion, people may not answer interview-style questions accurately for various reasons: perhaps our questions are unclear, we ask about culturally sensitive subjects, or people may be unsure what we are going to do with the information they provide.

In such cases, participatory methods—activities carried out by groups of villagers—can provide opportunities for larger numbers of people to give their perspectives on a subject in an open setting, with some "cross-checking" built in to the process. This family of methods, called PRA (Participatory Rural Ap-

praisal) among other names, can help field workers quickly obtain more accurate information from groups of people. With a PRA approach, this information can be gathered in ways that are (1) more interesting for villagers than surveys and (2) more useful for villagers than supplying answers through interviews. These activities can help villagers communicate their knowledge and needs in a form understandable to outsiders, as well as provide materials useful for internal discussion and planning. Practical examples follow. Complete handbooks in many languages are available on using PRA in different situations. You will find references to some at the end of this section. Here, we will give an overview of some of the most common methods and how they could be useful in your work:

For all the techniques outlined below, field workers must be attentive to the involvement of villagers. Schedule activities for times and places most comfortable for the participants, and be aware of who attends and how active they are. For example, there may be times of day when most women are too busy or far from the village to join activities, or seasons in which most men are working away from the community. The most convenient times for villagers may be late at night, or on a certain day of the week (e.g., immediately following a worship service). Choose a location which is suitable for all intended participants; if governmental facilities or religious buildings are not acceptable for everyone, an outdoor space may be a better choice.

Pay attention to how many people of different social groups are represented: age, gender, educational levels, relative status, and other factors. Do some groups or individuals take over, while others remain in the background or leave after the activity begins? It is your responsibility to observe participation, keep a record of who was (or was not) active in the activity, and to encourage those who are more reserved—or with lower social status—to be involved. Considering your cultural context, you will have to evaluate whether different groups should work together or do separate activities and then compare results, or you could assign different tasks for certain groups to fill in aspects in which they have special knowledge. (Handbooks provide many practical ideas to monitor villagers' involvement.)

Methods and techniques

Participatory mapping is one of the most common starting points for learning about a community. Natural resource maps enable villagers to communicate about their environment and to indicate the places and features most important to them. Village maps can convey information such as population, family size and extended family relationships, educational levels and health status of different households, and locations of current water sources; or in discussing locations for new buildings, placement of new water taps, or community gardens. Individual field maps can be made by a farm family to show what trees and annual crops are in their plots, to explain past planting patterns and future plans, and to indicate particularly fertile or problem spots in the gardens.

Villagers in West Papua (Indonesia) completed a natural resource map of their tribal lands. The map shows rivers, mountains, plants and animals of the region. Photo by Laura Meitzner Yoder.

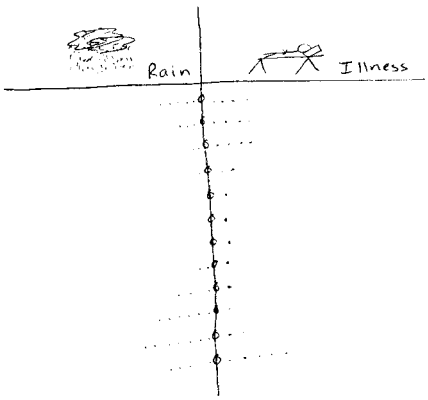
Community map-making can be done with paper and pencil, chalk on wood, or whatever materials are around such as stones, bamboo, leaves, flowers and branches. In situations where few people are literate, drawing on paper might be dominated by the literate individuals who are comfortable holding and using pencils, so other techniques may be more likely to achieve broader involvement. Village maps using local materials can be fun and usually draw quite a crowd. One village in Indonesia used sand piles to build contours over an area six meters square; bamboo channels with water for the path of the river; large leaves to indicate houses; stones and seeds to indicate the numbers and types of animals owned by each family; and different flowers lined up behind each house for the parents, children, and other relatives in each house, as well as symbols for children who had died.

Doing activities directly on paper provides an immediate and "original" written record, but usually includes input from only the few people who can fit around the paper. In addition, many villagers feel that something written on paper is no longer open to correction, so they may not suggest changes as readily as when they can debate and agree on where things are, then rearrange physical symbols. Using moveable symbols involves many more people and can be used in a large area, but can be quickly disrupted if an animal races through the map or it rains. In order to have a permanent record of the villagers' map, the field worker or an assistant will have to copy the map onto paper, being careful to pay attention to scale and completeness of the drawing. Always take a photo of the map with the villagers who made it, and return multiple copies to the community.

You will have to adapt your technique to the immediate situation and people group. In one map, which covered a vast region of forest, villagers used chalk to draw rivers, mountains, and land boundaries on the wood floor of a school room. They then had one day to review, discuss, and correct other people's sections of the map. Once the natural features were agreed upon by everyone, villagers gathered again to "fill in" the map with locally important plants, wild animals, and historically significant places. The villagers included unexpected features, such as the places certain birds go to drink water or the best places to find pet animals for children.

In all of these methods, the primary participants are the villagers. The role of the field worker is to prepare for the activity, by talking with individuals and explaining the process to local leaders. Once a time and place are set and publicized, the field worker or local counterpart can outline the purpose and mapping process to the villagers who will be making the map. Once people begin making the map, the community takes the active role, and the observer should ask questions (e.g., "Are there other sources of water in different seasons?"), but not give directions (e.g., "Now put in the mango trees by the path there"). Having an outsider directing what should or should not be in the map causes people to lose initiative and become passive or dependent on outside instructions. The process will be more vibrant and the product more internally legitimate and useful if villagers feel it is *their* map. A village and natural resource mapping activity usually takes two to three hours, plus time to draw the map on paper and check the accuracy of the drawing with local people.

It is important to be clear with the villagers beforehand what will happen to the map, and to return a good copy to the village for safekeeping once the process is completed. Some people may fear that the map will be used to increase their taxes, or "give away" the secrets of their local resources, or somehow be used against them. Sometimes a map or other activity is best carried out separately by groups of villagers (women/men, young/old, newcomers/long-term residents), for comparison and to allow each group to share their perspective and knowledge as basis for a discussion. Work with local leaders beforehand to clarify the process and answer questions. If people are uncomfortable with the results of their activities being shared with others, we need to respect their wishes.



Calendars can illustrate villagers' perception of relationships between different factors, such as the connection between rain and illness.

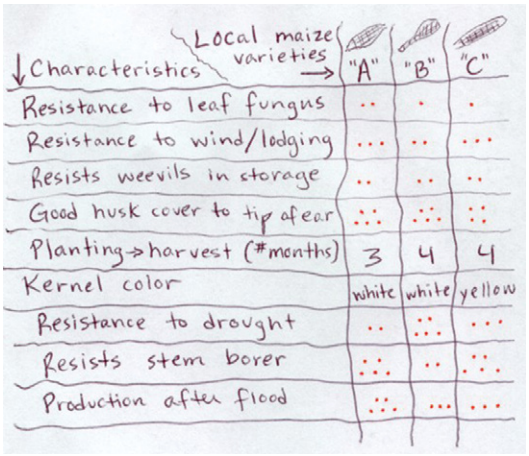
Maps may be used as foundations for diagrams, to trace labor patterns of different family members or to highlight connections among various parts of the farm. One community researcher in Honduras helped village families sketch local maps, and then used different color markers to trace walking paths and areas of activity for men, women, girls, and boys. This helped her understand who had responsibilities for pasturing animals, planting and weeding fields, selling produce, fetching water, gathering fuel wood from different sources, and caring for disabled neighbors. Diagrams at the regional level can trace the diffusion of new plant varieties, or the flow of income through the community.

Calendars are another useful technique for gathering information about seasons, agricultural cycles, labor availability, and perceived relationships (such as the connection between rain and illness, or drought and pest outbreaks). Annual or multi-year cal-

endars can show patterns over time. A calendar can visually identify seasonal shortages in different kinds of foods, and can help begin discussion about crops which may alleviate the hungry season. Drawing the crops produced in individual fields over the last decade can help clarify rotation and fallow patterns.

Timelines help record community history. In areas where people do not keep track of calendar years or people's ages, a timeline of important events (e.g., earthquakes, droughts, or changes in political leadership which can be verified through other sources) can help newcomers correlate occasions which mark time for the villagers with other events. Many communities have never had a written record of their history, and they appreciate this activity. Timelines can be posted in schools or public buildings and may be gradually completed. Using pictures in addition to words will make the information accessible to children and adults who cannot read.

For understanding local ecological zones, a transect gives a quick sketch of the different production areas. A transect diagram (as used in PRA) is a drawing of the features across some distance, such as a mountain slope or a river valley. For example, the diagram would point out the different vegetation types and changes in altitude in a region. Another common PRA technique is "transect walks," in which you draw the terrain on a "guided tour" with villagers. A transect can highlight information on natural vegetation and agricultural activities of different zones, as well as localized production problems (flooding, erosion, etc.) or valued products (fuel wood, edible snails, medicinal plants, building materials, etc.) from different regions.



Matrix scoring: farmer evaluations of local maize varieties.

Matrix scoring is a powerful tool for villagers to compare and evaluate various options. For example, Honduran farmers from the same region created a matrix to compare varieties of native maize.

Sample ears and names of the varieties are across the top of the matrix, and important characteristics are listed down the side. Then the group discusses how each variety performs for each trait, and gives a score of 1 to 5, with 3 being average and 5 always being the "positive" or "best" score.

This information can then be used by plant breeders to learn what traits are most important to farmers, to identify native varieties with exceptional traits for breeding programs, or to understand what needs could be addressed in a native maize improvement program. In Honduras, some farmers learned of other local varieties with traits of interest to them, and they exchanged seed and carried out their own crosses to incorporate the new traits. The matrix exercise provided the opportunity for farmers to discuss maize characteristics in detail and to learn from each other's experience, as well as to communicate their knowledge and needs to plant breeders.

References for further reading

Challenging the Professions: Frontiers for Rural Development by Robert Chambers. This book provides a thorough theoretical background and history of techniques for learning about communities. If you are a new field worker, Chambers alerts you to various factors which can make your questions and observations much more effective as you learn about your new area. (Chambers told me they printed this short book specifically to be inexpensive enough for people in the field. I would put it on my “Top Ten” list of recommended reading for departing workers and all interns. Very digestible).

The Institute of Development Studies (IDS) is an excellent source of information on techniques and uses of PRA. If you e-mail them, please be specific in your request. Their contact information is as follows:

Institute of Development Studies at the University of Sussex
Brighton
BN1 9RE
UK
Tel: +44 (0)1273 606261
Fax: +44 (0)1273 621202
e-mail: ids@ids.ac.uk

The Indigenous Knowledge and Development Monitor was a journal that served the international development community and all scientists who share a professional interest in indigenous knowledge systems and practices (IKSP). The Monitor, produced by Nuffic-CIRAN in cooperation with the indigenous knowledge resource centers in various parts of the world, ceased as of December 2001. Back issues may be found at: www.iss.nl/ikdm/IKDM/IKDM/index.html

1.3.2 TOWARDS MORE FRUITFUL AGRICULTURAL EXPERIMENTATION

By Mark MacLachlan, SIM (Serving in Mission), Ethiopia

For many of us the idea of "research" is scary. We are not trained in it. We picture rigorous statistical analyses that we are unfamiliar with. We have seen glossy scientific journals with technical words that we do not understand. Besides, isn't our goal to directly help smallholder farmers? Why should we now do research? Who has time anyway?

Chances are that most of us are already involved in doing experiments at some level, but we just don't call it "research." We wish we had more information about some crop or agricultural technique, so we do a small variety trial or set up a demonstration to see if the idea works in our climate. How will this information be generated and distributed if not by those of us in the field? And how will we know that we can safely implement or recommend some new method or plant unless we have done adequate experimentation?

Each of us has limited time and resources, but with a little thought, most of us can make the trials we are already doing more useful. Anyone who has ever placed a seed in the soil and watched it grow can participate, at some level, in experimentation that is useful to everyone.

Imagine a missionary or extension agent who thinks that a certain plant might be useful in his area. He plants a small plot, though he does not record how much seed was used, the date it was planted, what the site conditions were or what method was used to plant it. After some time he finds that the plants *did* grow, and he ate the harvest. He can only guess how much was produced. All he learned was that the crop seemed to do well and that he liked the food it produced.

Is that kind of experimentation useful? Yes. He learned what he wanted to know. Gardeners around the world do this kind of trial all the time and accept the results of their trials as valid. But the usefulness of his trial could easily have been increased. Chances are he will not keep the information to himself. At the very least, he will show it to the people around him (farmers and development workers alike). He may even send an email to ECHO, where the information will be tucked away in a plant file, to be discovered at a later date by an intern preparing a research note. And that very anecdotal information will have enriched in a small way the knowledge base of the ECHO network.

There is a temptation to avoid doing experiments because we are not trained researchers or we lack resources. But instead of giving up completely, we should do experimentation using the resources we do have. We may not have the skills for statistical analysis, but we can take an average of a group of numbers.

In planning any experiment, we should consider the target group. If our target group is university professors, we had better toe the line with our statistics. If our target group is uneducated farmers, we need to

figure out what criteria they will accept to validate our trials, since statistics are probably useless to them. I call this “resource-appropriate experimentation.”

There are many simple ways to make agricultural trials more useful. The first step is to gather information. This is often referred to as conducting a literature review. For resource-appropriate experimentation, valuable information can be gathered locally. For example, it may be obvious to a local farmer why your trial will not work, because he or she has been around longer and has connections that you may not. You may learn that another missionary or development worker was in the area ten years ago and experimented with many things. See if you can locate him or her. You may not have access to a university library, but the Internet is a very useful tool.

Another step is to keep written records. Merely measuring the amount of seed planted, recording the length of time until germination, and recording the amount of harvest is valuable and gives more information than nothing at all. Ask at the start of your trial, “What information can I collect that will increase the value of this trial to me and to others?” These records (measured values) can then be used to calculate averages. You may decide later that more elaborate statistics are appropriate. But remember your target group. Will the statistics help convince the people who most need to be convinced about the value of a method or plant?

The next step is to document and share results. University research results are usually published in journals. For resource-appropriate experimentation, there are other, simpler ways to get information into broader circles. You might write letters to others who are interested, send information to ECHO, include results in newsletters, or post findings on your own or another’s web site. The feedback can be encouraging. Our experience in Ethiopia has shown that appropriate experimentation is contagious. One of the joys in our work is the number of people who have come to us with new ideas they want to try. They saw that our research about local trees was done simply but effectively, and they were encouraged to do the same.

Our results will be more convincing if we show similar results from more than one trial. The academic community calls this replication. A method may work or a plant may grow well this year, but what about next year? It worked on the east side of the farm, but what about the west side? It was fine on this end of the row, but what about the other end? When results are shared, others can duplicate what we have done, perhaps on a wider scale. This can help reveal limitations of a particular method or plant.

Do not let the rigors of formal publication scare you away from documenting and sharing the good information you have found. On the other hand, if you have the knowledge and experience to publish formally, go for it!

Another way to improve our experiments is to find someone to review the research and give suggestions. The academic community refers to this as peer review. The purpose is to make our trials more accurate, and the information more usable. Who should be the experts who review our trials? Maybe this could be done by the farm families that we hope will utilize the results. Certainly other missionaries and development agents doing similar work should be consulted. A professional researcher could give good suggestions if we intend to do more formal research. But the important thing is to get outside input from somebody, preferably on an ongoing basis.

Most of us have a vision that exceeds our present circumstances. Experimentation is a way to reach beyond our immediate situation. Research catches the eye of government officials. Experimental results, when shared, can be useful in places where the missionary or development worker would otherwise not have influence.

I tended to think I was not doing real research because I was not participating in the “formal research” community. But when I looked at what we were doing, and evaluated it from the standpoint of different criteria, I found that my experimentation was a lot more advanced than I had thought. I also saw ways to improve it.

Experimentation can be a bridge between highly educated people and target groups in poverty. Anytime we can get a government official to see things from a farmer's perspective, we are doing the farmer a favor; and sharing findings, based on an experiment that is done well, can accomplish just that.

For the educated, our experimentation serves as a model and may lead to better ways of working with farmers and their families. For the farmers, our experimentation can provide them with opportunities to share their expertise. For those of us who are foreigners in the areas where we work, research is an opportunity to be in a community as a learner, and the learning role is much more acceptable to most communities than a "know-it-all" attitude. A properly conducted experiment can also serve to make our presence more valuable to the government of the countries in which we work.

Can we do experiments to glorify God? Is research a valid path to bring Him glory? I believe so. God put Adam in the garden to work it and take care of it (Genesis 2:15). The "garden" still needs careful attention. Who is closer to working and caring for the garden than the farm families of the developing world? When we stand with them (through development work that is founded on experimentation) we care for the garden with them, and act in obedience to God. When we obey, He is glorified. If we encourage farmers to make changes based on shoddy methods (based on poorly-conducted, insufficient or no research), we can expect that our care of His garden will be less than the best.

1.3.3 FORMALIZE YOUR RESEARCH: HOW TO CARRY OUT AN AGRICULTURAL EXPERIMENT

By Edward Berkelaar, PhD, former ECHO staff

As you work in agricultural development, there may be times that you find yourself wondering about the answer to a specific question you have. For example, should plants be spaced 30 cm or 60 cm apart to achieve the highest yield? Which one of three tomato cultivars would grow best in a particular area? Would growing a cover crop in the off-season result in higher corn yields? Once you decide on a particular question that you want answered, several steps can (and should) be taken. These steps will make the best use of your time and efforts while giving you the most confidence in your outcome. This section will cover the important steps in planning and carrying out an experiment and then apply them to a sample experiment. In some instances we have used technical terms, but please do not let them discourage you. We have tried to define the words well, and have highlighted them for clarity.

Know your question!

The first step in conducting a proper experiment is to know exactly what you are asking; the simpler and more specific the question, the better. For example, "Which tomato variety should I recommend in this area?" is a poorly worded question. It is vague and should be narrowed down as much as possible. Perhaps you are in a hot area and already know that you can discount any tomato varieties that were not developed or bred for tolerance to heat. A better question would be: "Of the tomato varieties A, B, C, D, and E, which has the highest marketable yield?" The question you ask is closely related to your research hypothesis, which in this case would be: "One of the five cultivars A, B, C, D, and E yields better than the others"; or "Not all of the cultivars have similar marketable yields."

For statistical reasons, it is important to be able to come up with what is called a null hypothesis. This is the opposite of your research hypothesis. In this case, the null hypothesis would be "The tomato varieties A, B, C, D, and E have the same marketable yield." This kind of statement does not seem to make sense, but it is important because the use of statistics cannot prove a hypothesis, but it *can* provide information about a null hypothesis. For example, if the statistical analysis of data suggests that the marketable yields of the different tomato varieties are NOT the same, then you can conclude that the varieties do not all produce the same marketable yield. A similar process can be used for comparing plant spacing, pruning techniques, rates of fertilizer application, etc.

Literature search

Once you know your question, spend some time looking for information that has already been collected on the subject. Maybe a local research station has done variety trials and the information (or some of it) is already available. Perhaps a variety trial was done years ago or in another location, and you can see how some newly available varieties compare to others that have been around for a while. You may find guidelines explaining how previous variety trials were done, even if they were for a different crop. Often, the result of a literature search is that you want to modify your question. In the process of doing a literature search, you will become better acquainted with your subject area and end up with a clearer question that you want answered.

Plan your experiment: replicate, randomize, and include a control

The next step is to plan your experiment. First of all, what do you want to compare in your experiment? You might want to compare several varieties of a particular species of plant (this is called a "variety trial"), or you might want to do an experiment that involves treating plants of the same variety in different ways (e.g., you space some 30 cm apart and space others 60 cm apart). In the latter case, each way that you treat the plants is referred to as a treatment.

When planning an experiment, there are three extremely important procedures to carry out: replication of treatments (or varieties), randomization and having a control (that is included as one of your treatments).

Replication

Replication means that you apply each treatment to several different plants (or rows, or plots) instead of just one. Using two plants, rows, plots, etc. is replication, but is not enough—you should have at least three replicates for each treatment (or variety). It is important to replicate within the different treatments because you want your results to be as accurate as possible.

For example, if you want to know if females and males in a population have the same average height, the most accurate way to do this is to measure the height of all females and all males, take the average, and then compare them. Clearly, it is not realistic to try to measure the height of all those people. Instead, the population is sampled, and that sample is measured. If you only select one male and one female, you may have chosen a tall woman or a short man, without knowing that these individuals are not "average." By replicating (e.g., measuring the height of 8 males and 8 females), you are likely to get a more accurate idea of the average height of females and males. It is still possible, though much less likely, that you would choose 8 unusually tall women or unusually short men for your measurements. Replication also provides information about the uniformity of a population. For example, are most women similar in height, or do the heights vary widely?

As another example, assume you have a small field with 10 rows that are each 40 m long, and you want to know the yield per given length of row of five tomato varieties. One option would be to fill each row with one of the five varieties (Fig 1.3a). This way you could plant each cultivar twice, and have two measurements (replicates) per cultivar. Alternatively, since 40 m rows are quite long, you could split them in half (20 m sections), or even quarters (10 m sections) (Fig 1.3b and 1.3c). This would give you an opportunity to have four, or even better, eight replicates per variety. The only difference would be that instead of yield per 40 m, results would be in yield per 20 m or yield per 10 m. It would involve a little more work because you would need to mark off more sections and make more labels. You would need the same amount of land and the same number of plants. Statistically, you have increased the power of your experiment tremendously. You cannot analyze your experiment using statistics if there are no replicates (e.g., if you plant only one row of each variety and measure the yield of each row). The more replicates, the better off you are (try to do at least three); however, having more than 10 replicates is generally unnecessary in agricultural experiments. For some experiments (e.g., variety trials), it is also important to repeat them in different years to account for differences in growing conditions from one year to the next.

Randomization

The second important concept is to randomize the location of your various treatments (varieties in this example) within the field. This ensures that the different varieties or experimental treatments are planted or distributed randomly, instead of having all of one kind in one place and all of another kind in another place. Randomization is necessary because the growing conditions (e.g., soil environment) in your plot may vary from one area to the next. Maybe a plant variety performed well in your experiment, not because it was a superior variety but because it was placed where it was more fertile (perhaps fertilizers were not applied evenly or the natural fertility of the soil differed from one area to another). Perhaps one area of the plot was a low point in the field, so that the soil there was wetter. Or maybe one edge of your plot was bordered by a row of trees and received a bit of shade during part of the day. The "magic" of statistical analysis is that it can give you confidence about whether the difference in crop performance you measured was actually due to treatment or to some other factor.

It is important that conditions be as uniform as possible throughout your research plot, but since conditions can never be made exactly the same, it is important to randomly spread differences in your plot among the different treatments. [Ed: See the *Technical Note*, "Statistical Analysis of Simple Agricultural Experiments," or browse the literature for information on the "Randomized Complete Block Design," which is an easy and effective way to deal with the lack of uniformity in a field (e.g., if the land is sloping with differences in soil moisture between highest and lowest points of the field).]

Here is the easiest way to randomize if you want to plant a variety trial. First, mark out as many planting beds as you need (the number of varieties that you are testing multiplied by the number of replicates). Next, write the name of each variety on a small piece of paper. For each variety, you will need as many slips of paper as there are replicates. Next, put the slips of paper in a bag. Then go to your first planting bed and remove one of the slips of paper—that is the variety you will plant first. Continue doing this until all the varieties are planted.

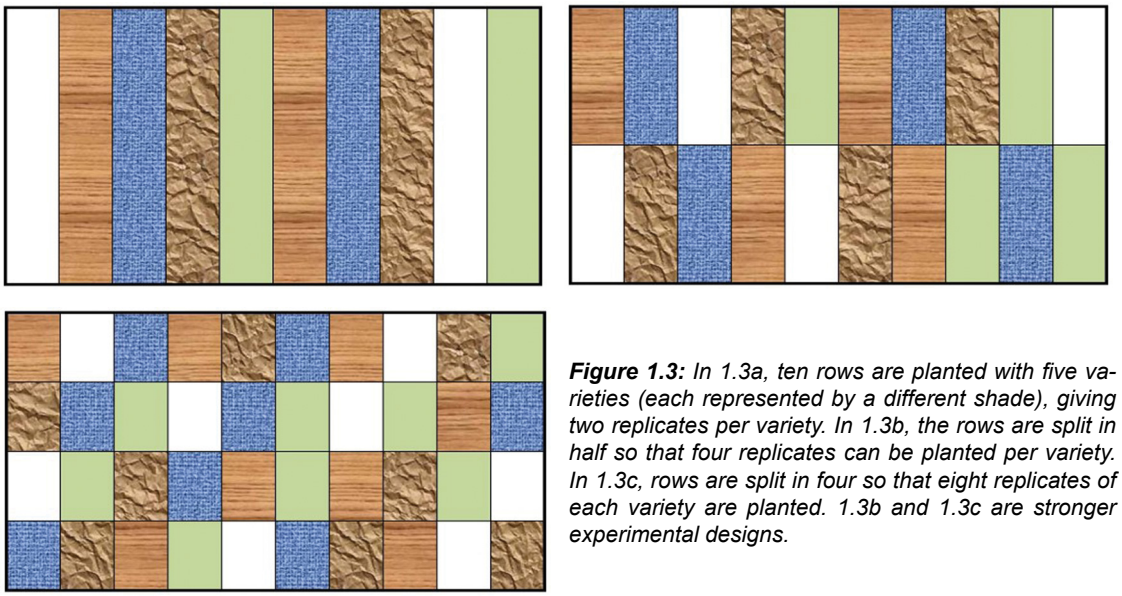


Figure 1.3: *In 1.3a, ten rows are planted with five varieties (each represented by a different shade), giving two replicates per variety. In 1.3b, the rows are split in half so that four replicates can be planted per variety. In 1.3c, rows are split in four so that eight replicates of each variety are planted. 1.3b and 1.3c are stronger experimental designs.*

Use a control

A control is the variety or treatment to which others are compared. It is important to include a control as one of your treatments, and sometimes it is useful to include more than one. Imagine an experiment in which a new growing technique is tested and results in an excellent crop yield. Including the old growing technique as a control allows you to determine if the high crop yield was due to the change in growing technique or to another factor such as an optimal growing season. If you want to do a variety trial, it is always good to include at least one commonly grown local variety. Since controls are exposed to the same

conditions (both good and bad) as your other treatments, they serve as an excellent point of comparison. Controls should be replicated and otherwise treated the same as your other treatments. A control is essential; it would not be acceptable to simply compare your results to data from yield of a previous year, or to compare your results to published data. (It is okay to compare results with published data, but comparisons should also include a control.)

Record observations and data

A written report of your method and final results is important if you want to share this information with others—or even remember it yourself in future years. Others may try your technique, and it may not work. In such a case they will be very interested to know why not. What type of soil do you have? What were your weather conditions like? What time of year did you do your experiment and how long did it last? Did you fertilize your soil and, if so, when? What kind of fertilizer did you use, and how much? Did your plants suffer from any type of disease or pest? Information like this might explain why an experiment led to different results when it was done at a different time or in a different location. For example, if two tomato variety trials were carried out, it would be informative (but also a bit confusing) to know that in the first trial, Variety A performed best and in the second trial, Variety D performed best. It would be helpful to know that during the first variety trial, the weather was cool and damp while in the second variety trial, conditions were hot and dry.

At the end of your experiment, record your data. The way you measure yield should be chosen carefully to ensure that it answers the question you are asking. Make sure you treat all of the plants in the experiment equally. Harvest everything at the same time if possible. If this is not possible, try to harvest at least 25% of each treatment at one time rather than everything from one treatment one day and everything from a second treatment the second day. If more than one person is harvesting, clarify the standard used to decide whether fruit should be harvested, discarded, or left on the plants for future harvests. With more than one worker, it is also advisable to switch halfway through harvesting a treatment, so that one person doesn't harvest treatments A and B only while the second person harvests C and D only. This can be another source of error when you are analyzing results; perhaps one person is a sloppy harvester, or has a different technique than the other.

Summarize your data: Statistics

Statistics are used to summarize data. It is important to understand what statistics can and cannot do. Statistical analysis relies on probability. It can allow you to know if the averages of two columns of numbers (treatment 1 and treatment 2, or variety 1 and variety 2) are different from one another. Statistics will give the answer to that question along with a probability. In agricultural experiments, that probability is set at 0.05 or 0.01, meaning that although you might conclude that the averages are different, there is a 5% or 1% chance that your conclusion will be wrong. This is a fairly small chance. In contrast, you would not have confidence in a conclusion that had a 25% chance of being wrong (a probability of 0.25).

For example, if you have two averages, 9.2 and 12.6, are they statistically similar or different? The answer to this question depends on two things; the difference between the two numbers (3.4 in this example), and the variability in the numbers the average came from. If 9.2 is the average of 8.2, 9.0, 9.7, and 9.9, while 12.6 is the average of 10.8, 11.7, 12.9, and 15.0 (i.e., in each case, the numbers are similar to the average), then we might conclude that the averages are not similar. On the other hand, if 9.2 is the average of 4.7, 5.8, 12.3, and 14.0, and 12.6 is the average of 3.9, 9.1, 16.5, and 20.9 (i.e., the numbers that make up each average vary widely), then we are faced with a different situation, and we cannot conclude that 9.2 and 12.6 are statistically different from one another.

Write a report

Once the data have been collected, analyzed and conclusions have been drawn, it is important to write a brief report. The report should contain several sections. In the Introduction, it is important to include the question you asked, why it was important, and any additional relevant information you discovered

while doing your literature search. The second section, Materials and Methods, should describe exactly how you carried out the experiment (the materials and methods you used to actually do the experiment). This section should be written in enough detail that someone could repeat your experiment using your description. The final section of the report is called the Results and Discussion section, and contains the data you collected along with conclusions you drew. Results from statistical analysis are typically included here, along with any ideas you might have regarding why the results came out the way they did. At the end of the report it is important to list any publications you referred to, so that others reading your report may also find and refer to them.

1.4 SELECT SUITABLE TROPICAL CROPS

1.4.1 UNDERSTAND GLOBAL WEATHER AND CLIMATE

By Richard James, Prescient Weather

Richard James is a meteorologist who has worked in both the academic and private sectors. Prescient Weather is a company that provides weather and climate information for risk analysis.

Many in ECHO's network have taken on the responsibility of establishing an agricultural development project in a country far from home and mostly unfamiliar. Often they and others involved in agricultural development wish for a better understanding of local weather and climate patterns so that agricultural planning can be successful. Location-specific climate information is valuable for coping with rainfall extremes, choosing which crops to work with, and determining the best time of year to prepare fields for planting.

In recent years, global weather and climate monitoring has grown in sophistication, and detailed, up-to-date weather information has become increasingly accessible via the internet. This article documents some online sources of weather and climate information and provides some guidance concerning the interpretation of available data. Section 1 discusses climatological data, Section 2 addresses real-time weather monitoring, and Section 3 explains how the status of the 'El Niño' effect can help anticipate future rainfall trends.

Climatological data

Weather observations over periods of at least several decades provide an understanding of the long-term average, or "climatology," of weather for any given location. Since the 1970s, global observations have been greatly improved by satellite monitoring, so that climatological information is available even for remote locations. A good source for climatological data worldwide is the website of the International Research Institute for Climate and Society (IRI): www.iridl.ldeo.columbia.edu/maproom/.Regional/

The climatology links provide access to high-resolution maps showing the average monthly temperature and average monthly precipitation for various regions of the globe. After selecting "climatology" for one of the regions, the "select a point" links allow the user to obtain data at any location over land on a grid of points with spacing of 0.5 degrees latitude and longitude [this distance for latitudes is about 35 miles (56 km); the distance of 0.5 degrees for longitude depends on the distance from the equator, since longitudinal lines get closer together the farther you are from the equator]. For the selected grid point, the website provides charts showing the distribution through the year of precipitation, temperature, frequency of rain, and frequency of frost. The "select a point" data can also be accessed from: www.iridl.ldeo.columbia.edu/maproom/.Global/.Climatologies/Select_a_Point/

When using a 'gridded' climatology map such as the one provided by IRI, it is important to bear in mind that each grid point represents an average over a substantial area of the earth's surface, and therefore local effects may not be represented properly. For example, differences in elevation or proximity to water bodies may greatly alter the climate at a specific location, but a coarse grid will not capture these effects. In such instances, historical weather observations from the precise location are needed to accurately de-

scribe the local climate. Historical 'station' observations do exist for many of the more significant population centers globally. These records may sometimes be accessed via an online search, but unfortunately there is no comprehensive online source.

Real-time monitoring

Meteorologists sometimes remark that "normal weather never occurs," meaning that weather is ever-changing and that weather observations rarely match the long-term climatological norm. Because significant departures of weather from "normal" create important, and sometimes dramatic, effects on agriculture and society, up-to-date (real-time) monitoring is critical for understanding evolving global weather scenarios. To assist with interpretation, weather data from the recent past is often expressed in terms of both the weather that has occurred (temperature, precipitation, etc), and the weather 'anomaly,' which is the departure of these weather conditions from normal.

IRI provides a modest selection of maps of temperature and precipitation anomalies in the most recent 1 and 3 month periods, under the first URL listed above.

A more comprehensive set of maps showing recent precipitation anomalies is provided by the Climate Prediction Center (CPC) of the U.S. National Weather Service:

www.cpc.noaa.gov/products/fews/global/

After making the regional selection, click on the "rainfall estimates" link. Then you can choose monthly maps of precipitation, precipitation anomaly (i.e. departure from normal), and percent of normal precipitation. Note that these precipitation maps are obtained from geostationary satellites, which are located above the equator; consequently the data are only reliable between approximately 30°S and 30°N. Although the data are displayed up to 60 degrees of latitude, they should be regarded as unreliable between 30° and 60°.

An important caveat concerning "percent of normal" precipitation maps is that many regions of the world experience dry seasons in which little or no rainfall occurs. In these months the 'percent of normal' is not well defined. In such instances, maps of 'percent of normal precipitation' may show apparently excessive dryness or wetness that is not truly meaningful. For this reason, precipitation anomaly maps should always be interpreted in light of the local climatology.

The CPC also supplies a more extensive series of precipitation monitoring maps for Africa and for South Asia:

www.cpc.noaa.gov/products/fews/AFR_CLIM/afr_clim_season.shtml

www.cpc.noaa.gov/products/fews/SASIA/climatology.shtml

Because these maps combine station observations with satellite data, they represent a higher quality of data than the satellite-only maps. At the bottom of the Africa page is a useful tool ("Time Series Plots") that provides up-to-date charts of recent precipitation observations from individual stations across Africa. These station observations may be compared with the maps to check consistency, or to obtain the "ground truth" at selected locations.

Seasonal forecasting

Although it is impossible to predict individual weather events beyond approximately 7 days into the future, it is sometimes possible to anticipate long-term weather trends that evolve slowly over periods of months or even years. Long-range or 'seasonal' forecasting depends on the fact that weather patterns are driven to some extent by patterns of temperature at the surface of the world's oceans. Phenomena such as El Niño, which consist of widespread changes in sea surface temperature, develop and persist over the course of months or years, and therefore provide useful predictability well beyond the range of conventional weather forecasts.

The “El Niño–Southern Oscillation” (ENSO) is the most important ocean cycle for seasonal weather variability. It is defined by sea surface temperature anomalies (departures from normal temperatures) in the equatorial Pacific Ocean. Widespread ocean warming is observed in El Niño, but La Niña brings unusually cool sea surface temperatures. As a prediction tool, these ENSO maps indicate the percent likelihood that precipitation will be above normal for either ENSO phase. Some of the most notable effects of ENSO on global precipitation are:

- East Africa tends to be wetter than normal in El Niño between September and February; opposite for La Niña
- Northern South America tends to be drier than normal in El Niño in both northern Hemisphere winter and summer; opposite for La Niña
- El Niño tends to bring pronounced dryness in the vicinity of Indonesia at all times of the year, but especially from September to November; unusual wetness is more likely in La Niña

The current status of ENSO, and indications for the next few months, can be obtained from IRI at:

iri.columbia.edu/climate/ENSO/currentinfo/QuickLook.html

The online maps show the precipitation anomalies that are most likely to prevail if El Niño is presently occurring or is predicted to occur, or if the same is true of La Niña. Bear in mind, however, that these outcomes are not guaranteed to occur. In general, the stronger the El Niño or La Niña episode, the more likely the effects shown in the maps will emerge.

Further information about ENSO is available at:

iri.columbia.edu/climate/ENSO/globalimpact/index.html

Ocean cycles other than ENSO also impose significant long-term weather anomalies on certain regions across the globe, and some of these cycles persist for years or decades. The understanding and prediction of this naturally-occurring variability is an area of active scientific research, and it is likely that improved long-range forecast methods will eventually result.

Summary

Modern communications technology provides ready access to a wide variety of information concerning historical and recent weather conditions, along with limited tools for anticipating future weather trends.

1.4.2 SELECT THE RIGHT CROP

By Dr. Franklin W. Martin

What question do we receive the most frequently from ECHO's network? Easily it is some variation of, "What crops can people consider for the region where I work?" Dr. Frank Martin put together a technical document for ECHO that was featured in AZ. Dr. Martin had mentioned the difficulty of assembling that kind of information and remarked, "The old-fashioned technique of a variety trial is still the best method to determine the value of a particular crop for your region."

Nevertheless, the Technical Note *he wrote contains valuable information providing guidance in selecting suitable crops for a given area. We thought it merited inclusion into this book as well.*

The information below contains multiple tables of reference. In one table, the most complex, he pulls together 140 crops, including both annuals and perennials, and vegetable, field and fruit crops. It will be useful as a rough screen to choose or eliminate crops to consider. Other tables list several plants based only on rainfall amount and distribution and on temperature. No attempt was made to prepare an exhaustive list. For each of these climates, he has chosen several useful and probably familiar plants that would

be well worth a try.

Introduction: "What crops can I grow?"

Consultants in tropical agriculture often receive letters from Peace Corps volunteers, teachers, missionaries, students, and those who have followed their careers to the tropics, with the question, "What crops can I grow?" Leaders and farmers often look for new alternatives to basic crops that do not bring in enough income and write, "What other crops can I grow?" Conscientious persons from the developing world, and even from academic institutions in the United States, ask the same question. Choosing the right crop or crops for a particular place is a common problem, and the information for answering the question is not necessarily widely available or easily found. Knowledge of agriculture tends to accumulate in regional pockets that represent ecological zones. While the majority of those that write may understand their own area quite well, they are much less familiar with the broader situation or the whole of the tropics and subtropics.

Improvement of Local Agriculture

Quantity and quality of agricultural produce, and usually the diversity as well, can always be improved. However, it is a mistake to assume in any situation that improvements are easy. Agricultural systems represent biological, socio-economic, and technical evolutionary adaptations to particular ecological systems. Agricultural systems are followed because they work under the local circumstances, or at least they work better than easily visualized alternatives.

It is sometimes relatively simple to improve the technology of developing-world agriculture, yet investigators are often puzzled why the technology is not readily adopted by farmers. Usually, the answer is in the frequently overlooked socioeconomic aspects of the system. In highly technical systems, yields and quality might already be high, and improving such agriculture is like shooting at a moving target—hard to achieve a hit.

Traditional approaches to answering the question

The most obvious and useful technique to answering the question, "What crops can be grown?", is to observe and talk with local farmers. They are wealthy in appropriate technology with deep, and sometimes almost poetic, understanding of their particular crops and production systems. Following farmers' techniques, especially those of farmerleaders or farmerinnovators, one is practically assured of a crop. Yet farmers have their roots in tradition. Even excellent farmers may be unaware of what other farmers do in an adjacent valley or region. They may not know of improved varieties or technological advances. They are seldom aware of the world situation, or at times, even the local market and how it affects their crops. Thus, the expertise of farmers is valuable but limited.

A second source of information is that of agricultural statistics. While few countries have as extensive a system as the United States, all countries maintain some records of production. These reords clearly show what crops are grown, and usually include acreage and yield. If a crop is already grown in substantial quantity within a region, then you can be sure it is one that not only can be grown, but that can also make money and can be improved.

A third technique is to talk to the local agricultural agent, or, if possible, the nearest agricultural extension office or experiment station. The structure of the system developed to help local agriculture varies, but these people have knowledge of the crops within their region. They know which crops the government emphasizes (usually the money-makers) and often the improved varieties and technology. Do not undeestimate them and their potential answers to your queries. While the above traditional sources of information may not be adequate, it would be foolish to start any serious long-term endeavor without consulting these sources.

A fourth technique is to observe the wild plants on the land as an indication of what crops can be suc-

cessfully produced. This technique has not been developed to the extent that it would be a useful tool, and has as a disadvantage the requirement of special knowledge of the local flora. Furthermore, in some regions the original native flora has been destroyed.

An integrated approach

This kind of approach utilizes local, national, and internationally available information to answer the question. The ecological situation is emphasized here. If one can learn to distinguish ecological zones and learns the ecological requirements and preferences of crops of the world, then one can match crops with zones with a high degree of confidence that a given crop can be grown in a given locality. But, even so, always remember that there are other questions to be asked.

Principal factors determining crop potential

The principal factors that determine crop potential are both internal (genetic) and external (environment). Not only do species of plants vary with respect to their genetic potentials and responses to environment, but even within a given species, different varieties or individuals are distinct in adaptation.

Availability of Water

Water occurs everywhere, including in the driest desert. Nevertheless, not all water is available for plant growth. For example, water in the air is not available to most plants. Since almost all crop plants grow in the soil, water availability, for practical purposes, is the water in the soil that is available for plant use. When excess water falls on the soil, a portion may run off even before it can enter, and part of that which enters will be held in the soil by physical and chemical forces. In dry climates runoff can be reduced by contour planting, by furrows oriented crosswise to rain-carrying winds, by plowing, and other treatments on the soil surface. Plants can also be planted at the bottom of furrows or in pits to increase their chance to obtain water. The remainder of the water will move deeper into the soil attracted by gravity until it comes to rest on an impenetrable basin or joins an underground stream or aquifer.

Water is lost from the soil not only by percolation downward but also by evaporation on the surface. The rate of evaporation depends on the water-holding capacity of the soil, and also on environmental conditions (chiefly temperature, relative humidity and wind). In general, sandy soils hold the least available moisture, while clay soils and soils of high organic matter hold the most. Water-holding capacity of a soil can be increased, for practical purposes, chiefly by the addition of organic material to the soil. Plants can remove water from the excess flowing through the soil, from basins or aquifers, and from water that is physically and chemically held in the soil, up to a limit. Water availability to a plant is also determined by its ability to retrieve water with a large and efficient root system. Competing plants (other crops or weeds) reduce the water available to a particular plant.

Seeds may need water almost continuously in order to germinate, and seedlings may need extra water to grow. Growing plants need large quantities of water, but may be very adept at obtaining it because of their root systems. A plant that matures in a short period may avoid drought by its ability to mature when water is available.

“Life zones” (as defined in Table 1.1 by Holdridge) depend, in part, on the amount of water received annually. The yearly average rainfall, much more than the extremes, dictates the kinds of woody perennial plants that can be grown without irrigation in a particular zone. The suitability of an annual crop for growth in a particular region, however, depends not only on life zone, but also on the water availability through irrigation and water conservation methods. Distribution of rainfall must also be taken into account in interpreting life zones. If rainfall occurs over a relatively short period, followed by a dry season, some annual crops might not be able to mature.

Temperature

Temperature affects plant growth directly and indirectly. As temperature increases, chemical activity increases. Thus, over a certain range, higher temperatures increase growth. However, protoplasm cannot survive excessively hot temperatures. At the other extreme, many plants cannot survive temperatures below freezing. Specific organs may be more susceptible to heat (flowers) or to cold (succulent tissues). Some organs, particularly some seeds, may resist both heat and cold. Furthermore, loss of water from plants and soil is increased by high temperatures, as well as by low humidity and wind.

Plants are adapted to particular climates, in part, by their ability to grow and reproduce at certain temperatures. Among vegetable crops, one can distinguish cool-season crops (e.g., cabbage and lettuce) from hot-season crops (e.g., corn and squash). Some crops, such as tomato, grow best where days are hot and nights are cool.

Altitude and Latitude

Altitude influences temperature and in this way affects plant growth. As altitude increases, temperature decreases. Latitude influences temperature by influencing the amount of light intercepted by a unit area. It also influences daylength, which, in turn, influences plant growth through hormonal mechanisms which are part of a plant's adaptability. For example, short-day plants flower best in short days. Long-day plants often flower best only during long days. Some plants are day-neutral and their flowering is not influenced by day length.

Thus, life zones are influenced chiefly by annual rainfall and mean annual temperature. In any region of the earth, a person should be able to determine the life zone by weather records.

Soil acidity

The acidity of the soil, defined in terms of pH, is a third important factor determining crop potential. While almost all crops grow well in soils with slightly acidic pH (6.5), crops differ in their tolerance of acidic (low pH) and alkaline (high pH) conditions. Soil acidity can be increased with the use of acid forming fertilizers (such as sulphates) and organic materials, or decreased with the addition of lime. Usually soils of the humid tropics are acid and those of the dry tropics alkaline, but there are exceptions.

Prediction of suitable crops

Use of Table 1.1 and 1.2

As a first step in determining whether a particular new crop (traditionally-used crops are obviously suitable) may be appropriate for your region, determine the life zone for the region from annual rainfall and temperature. Also, determine the normal pH of the soil of the region. Then consult Table 1.1 and 1.2.

A Second Step

You can use Table 1.3 if your region falls into one of the following categories: hot humid tropics; tropical monsoon; dry tropics; beach climate; wet, cool highlands; and dry, cool lowlands. Consult the portion of the table which corresponds to your climate and find the grains, legumes, vegetables and other crops most likely to be successful.

Table 1.1: Ecological or life zones of the tropics, subtropics and warm temperate zones.

Ecological Zones[1]	Mean Annual Temperature (°C)	Average Annual Rainfall (mm)	Symbol[2]
Tropical Desert Scrub	24 or more	125 - 250	Tx
Tropical Thorn Steppe	24 or more	250 – 500	Tt
Tropical Very Dry Forest	24 or more	500 – 1000	Tv
Tropical Dry Forest	24 or more	1000 – 2000	Td
Tropical Moist Forest	24 or more	2000 – 4000	Tm
Tropical Wet Forest	24 or more	4000 – 8000	Tw
Tropical Rain Forest	24 or more	≥ 8000	Tr
Subtropical Desert Scrub	18 – 24	125 – 250	Sx
Subtropical Thorn Woodland	18 – 24	250 – 500	St
Subtropical Dry Forest	18 – 24	500-1000	Sd
Subtropical Moist Forest	18 – 24	1000-2000	Sm
Subtropical Wet Forest	18 – 24	2000-4000	Sw
Subtropical Rain Forest	18 – 24	≥ 4000	Sr
Warm Temperate Desert Bush	12 – 18	125-250	Wx
Warm Temperate Woodland	12 – 18	250-500	Wt
Warm Temperate Dry Forest	12 – 18	500-1000	Wd
Warm Temperate Moist Forest	12 – 18	1000-2000	Wm
Warm Temperate Wet Forest	12 – 18	2000-4000	Wd
Warm Temperate Rain Forest	12 – 18	≥ 4000	Wr

[1]According to Holdridge (Holdridge, L. R., 1966, The Life Zone System, Adansonia 6(2): 199. See also: Holdridge, R. 1947, Determination of World Plant Formations from Simple Climatic Data, Science, 105 (2727):267368.

[2]NOTE: The capital letters refer to tropical, subtropical or warm temperate climates. The small letters are for types of vegetation as determined by the life zones. Using the chart below you can see that okra will grow in warm temperate dry forests, warm temperate moist forests, tropical desert scrub and tropical moist forest climates. Lifezone abbreviations (also used in Table 1.2) are detailed below:

T = Tropical	d = dry forest
S = Subtropical	m = moist forest
W = Warm temperate	r = rain forest
C = Cool temperate	w = wet forest
B = Boreal	v = very dry forest
t = thorn steppe (if tropical) or woodland (if warm temperate)	x = desert scrub (if tropical or subtropical) or bush (if temperate)

Table 1.2: Maximum ecological tolerances for some tropical crops.

Scientific name	Common name	Length[1]	pH	Rainfall (cm)	Temp range (°C)[2]	Life Zones[3]
Abelmoschus esculentus	Okra	A	5.1-7.8	30-250	13-27	Wdm,Txm
Agave sisalana	Sisal	P	5.1-8.3	20-260	15-27	Cm,Ttw
Aleurites fordii	Tung Oil	P	5.3-7.3	60-250	13-25	Wdm,Tdw
Allium ampeloprasum	Leek	B/A	5.2-8.3	40-270	7-23	Bu,Td
Allium cepa	Onion	B/A	4.5-8.3	30-410	6-27	Bu,Tvw
Allium sativum	Garlic	P/A	4.5-8.3	30-260	6-27	Bm,Tvw
Alocasia macrorrhiza	Giant Taro	P/A	5.8-7.3	70-420	15-27	Wd,Tm
Aloe vulgaris	Common Aloe	P	6.0-8.0	60-400	19-27	Wdw,Ttd
Amaranthus hypochondriacus	White Amaranthus	A	5.2-7.5	70-270	8-27	Cm,Tdm
Anacardium occidentale	Cashew	P	4.3-7.5	70-410	19-28	Sdw,Tvw
Ananas comosus	Pineapple	P	3.5-7.8	70-410	16-28	Wm,Tvw
Annona cherimola	Cherimoya	P	4.3-7.3	80-400	16-27	Wdm,Tmw
Annona muricata	Soursop	P	4.3-8.0	60-420	17-27	Wd,Tvw
Apium graveolens	Celery	B/A	4.2-8.3	30-460	5-27	Bw,Sdw
Arachis hypogaea	Peanut	A	4.5-8.3	30-410	10-27	Cm,Ttw
Areca catechu	Betel Nut	P	4.6-6.8	70-420	15-27	Sdw,Tvw
Arenga pinnata	Sugar Palm	P	5.8-8.0	70-400	19-27	Sd,Tm
Arracacia xanthorrhiza	Arracacha	P/A	6.3-6.8	70-130	15-25	Cd,Sdm
Artocarpus altilis	Breadfruit	P	5.9-8.0	70-400	17-27	Sdw,Tdw
Asparagus officinalis	Asparagus	P	4.5-8.2	30-400	6-27	Csw,Tvm
Averrhoa carambola	Carambola	P	4.3-8.3	70-410	18-27	Sdw,Tvw
Bactris gasipaes	Peach Palm	P	5.8-8.0	70-400	19-25	Sdw,Tmv
Bertholletia excelsa	Brazil Nut	P	4.5-6.5	110-410	19-27	Sm,Tdw
Brassica chinensis	Pakchoi	B/A	4.3-7.5	60-410	6-27	Bw,Tdw
Brassica oleracea	Cabbage	B/A	4.3-8.3	30-460	5-27	Bmw,Tdw
Brassica pekinensis	Chinese Cabbage	B/A	4.3-6.8	70-410	7-27	Cmw,Tdw
Brosimum alicastrum	Ramon	P	6.0-8.0	30-400	19-25	Sm,Tdw
Butyrospermum paradoxum	Shea Butter	P	4.9-5.2	130-140	26-27	Tdm
Cajanus cajan	Pigeon pea	P/A	4.3-8.3	30-400	15-27	Wmw,Txw
Calamus rotang	Rattan	P	4.2-5.5	170-420	19-27	Sm,Tw
Camelia sinensis	Tea	P	4.5-7.3	70-310	14-27	Wdw,Tvw
Canarium indicum	Canary Nut	P	7.1-8.1	110-230	25-27	Tdm
Canavalia gladiata	Swordbean	P/A	4.3-6.8	70-270	16-32	Wm,Tmw
Canna edulis	Edible Canna	P/A	4.3-6.8	70-400	7-26	Cm,Tdm
Capsicum annuum	Bell Pepper	A	4.3-8.3	30-460	9-27	Csw,Txw
Carica papaya	Papaya	P	4.3-8.0	70-420	17-29	Wm,Tvw
Casimiroa edulis	White Sapote	P	5.7-8.0	50-400	16-26	Wd,Tdw
Ceiba pentandra	Kapok	P	4.3-8.0	70-420	19-29	Sdm,Tvw
Ceratonia siligua	Carob	P	6.2-8.6	30-400	13-26	Wd,Sdm
Chrysanthemum cinerariifolium	Pyrethrum	P	5.2-7.5	70-260	8-27	Cmw,Sdm
Cicer arietinum	Chickpea	A	5.5-8.6	30-250	6-27	Wdm,Txm

Table 1.2: Maximum ecological tolerances for some tropical crops.

Scientific name	Common name	Length[1]	pH	Rainfall (cm)	Temp range (°C)[2]	Life Zones[3]
Cinnamonum verum	Cinnamon	P	5.8-8.0	150-390	20-27	Sdw,Tdw
Citrullus lanatus	Watermelon	A	5.3-8.0	30-400	11-29	Cw,Txw
Citrus aurantium	Sour Orange	P	4.8-8.3	20-400	13-28	Wd,Txw
Citrus limon	Lemon	P	4.8-8.3	30-410	11-28	Cw,Tvw
Citrus paradisi	Grapefruit	P	4.8-8.3	30-410	13-28	Wm,Tdw
Citrus sinensis	Sweet Orange	P	4.3-8.3	30-410	13-28	Wmw,Tdw
Cocos nucifera	Coconut	P	4.3-8.3	70-420	11-27	Sdw,Tvw
Coffea arabica	Coffee	P	4.3-8.0	80-460	11-27	Wdr,Tvw
Coffea canephora	Robusta Coffee	P	4.3-6.8	80-370	20-27	Sdw,Tdw
Cola nitida	Kola Nut	P	4.3-4.8	140-270	23-27	Sm,Tdm
Colocasia esculenta	Taro	P/A	4.3-7.4	70-410	11-29	Cw,Tvw
Crocus sativas	Saffron	P	5.7-7.8	50-110	6-19	Bm,Stm
Cucumus melo	Canteloupe	A	4.3-8.3	20-400	7-27	Csw,Txw
Cucumus sativus	Cucumber	A	4.3-8.3	20-460	6-27	Bmw,Txw
Cucurbita moschata	Pumpkin	P/A	4.3-8.3	30-280	7-32	Cmw,Tdm
Curcuma domestica	Tumeric	P/A	4.3-6.8	70-420	18-27	Sdw,Tdw
Cymbopogon citratus	Lemongrass	P	4.3-7.3	70-410	18-27	Wdw,Tvw
Daucus carota	Carrot	B/A	4.5-8.3	30-460	3-27	Bmw,Tdw
Dioscorea alata	Winged Yam	P/A	4.8-8.0	70-420	15-29	Wdm,Tvw
Dioscorea rotundata	African Yam	P/A	5.1-5.8	140-280	23-27	Sm,Tvm
Diospyros digyna	Black Sapote	P	5.1-8.0	70-420	19-27	Sdm,Tdw
Diospyros kaki	Japanese persimmon	P	4.3-8.3	30-460	13-27	Wdr,Tvw
Durio zibethinus	Durian	P	4.3-6.8	210-410	18-27	Ww,Tdw
Elaeis guineensis	African Oil Palm	P	4.5-8.0	70-400	21-27	Sdw,Tdw
Elettaria cardamomum	Cardamom	P	4.8-7.4	70-420	21-27	Sdr,Tvw
Eriobotrya japonica	Loquat	P	5.5-8.0	50-400	15-26	Wdm,Tm
Euphoria longana	Longan	P	5.8-8.0	70-400	19-27	Sdw,Tvm
Ficus carica	Edible Fig	P	4.3-8.6	30-400	9-32	Cmw,Txw
Fragaria spp.	Strawberry	P/A	4.5-8.3	30-260	5-21	Bmw,Sdm
Garcinia mangostana	Mangosteen	P	4.3-8.0	110-420	21-27	Smw,Tmw
Glycine max	Soybean	A	4.3-8.2	40-410	7-29	Cmw,Tvw
Gossypium barbadense	Sea Island Cotton	P	4.3-8.3	50-400	9-26	Csm,Tvm
Gossypium hirsutum	Upland Cotton	A	4.3-8.3	30-270	7-32	Cmw,Tvm
Helianthus annuus	Sunflower	A	4.5-8.3	20-400	6-27	Bmr,Tvw
Helianthus tuberosus	Jerusalem Artichoke	P/A	4.5-8.3	30-280	7-27	Csw,Tm
Hevea brasiliensis	Rubber	P	4.3-8.0	110-420	23-28	Smw,Tdw
Hibiscus cannabinus	Brown Indianhemp	A	4.5-7.4	50-400	13-27	Wtm,Tvw
Ipomoea batatas	Sweet Potato	P/A	4.3-8.3	30-460	9-27	Csw,Tvw

Table 1.2: Maximum ecological tolerances for some tropical crops.

Scientific name	Common name	Length[1]	pH	Rainfall (cm)	Temp range (°C)[2]	Life Zones[3]
Kerstingiella geocarpa	Geocarpa Groundnut		4.9-5.2	130-140	26-27	Td
Lablab purpureus	Lablab Bean	P/A	5.9-7.8	20-250	9-27	Wdm,Txw
Lactuca sativa	Lettuce	B/A	4.2-8.3	30-410	5-27	Bmw,Tdw
Leucaena leucocephala	Leadtree	P	4.3-8.0	70-410	16-29	Wdm,Tvw
Linum usitatissimum	Flax	A	4.8-8.3	30-130	6-25	Bmv,Tv
Luffa aegyptiaca	Sponge Gourd	A	4.3-8.3	30-420	13-27	Wm,Tvw
Lycopersicon esculentum	Tomato	P/A	4.3-8.3	30-460	6-27	Bmw,Tvw
Macadamia cultivars	Macadamia Nut	P	4.5-8.0	70-260	15-25	Wd,Tm
Mammea americana	Mamey Apple	P	4.3-8.0	70-400	19-27	Sdm,Tdw
Mangifera indica	Mango	P	4.3-8.0	20-420	17-29	Wm,Txw
Manihot esculenta	Cassava	P/A	4.3-8.0	50-400	15-29	Wdm,Tvw
Maranta arundinacea	Arrowroot	P/A	6.3-6.8	70-400	17-29	Sdm,Tdw
Medicago sativa	Alfalfa	P	4.3-8.3	20-250	5-25	Bmw,Txd
Moringa oleifera	Moringa tree	P	5.7-7.4	70-400	19-29	Sdm,Tvm
Mucuna pruriens	Velvetbean	A	5.1-6.8	70-310	17-27	Wdm,Td
Musa cultivars	Banana	P	4.3-8.3	70-260	18-27	Ww,Tvw
Myristica fragrans	Nutmeg	P	4.3-6.8	70-410	15-27	Wd,Tdw
Olea europaea	Olive	P	5.3-8.6	30-170	13-23	Wtm,Tvd
Opuntia ficus-indica	Barbary Fig	P	5.8-8.3	20-170	13-25	Wtm,Td
Oryza sativa	Rice	A	4.3-8.3	50-420	9-29	Csw,Tvw
Pachyrhizus ahipa	Yambean	P/A	4.3-7.3	150-410	21-27	Sdm,Tdw
Passiflora edulis flavicarpa	Yellow Passion Fruit	P	4.3-8.0	70-420	15-29	Wdw,Tvw
Pennisetum americanum	Pearl Millet	A	4.5-8.3	20-260	9-27	Wdw,Txd
Persea americana	Avocado	P	4.3-8.3	30-410	13-27	Wdm,Tdw
Phaseolus acutifolius	Tepary Bean	A	6.8-7.3	70-170	17-23	Wdm,Tv
Phaseolus lunatus	Lima Bean	A	4.3-8.3	30-420	9-27	Csw,Tvw
Phaseolus vulgaris	Kidney Bean	A	4.3-8.3	30-460	5-27	Csw,Tvw
Phoenix dactylifera	Date Palm	P	5.1-8.3	20-400	13-28	Wtd,Txm
Pimenta dioica	Allspice	P	6.3-8.0	70-370	21-26	Sdm,Tdw
Piper nigrum	Black Pepper	P	4.3-7.4	70-420	20-27	Sdw,Tvw
Pistacia vera	Pistachio	P	5.7-7.8	30-70	15-19	Wd,Std
Pouteria campechiana	Canistel	P	6.8-8.0	70-260	21-25	Sm,Td
Pouteria sapota	Mamey Sapote	P	6.3-6.8	150-400	23-26	Tm
Psidium guajava	Guava	P	4.3-8.3	20-420	15-29	Wdw,Txw
Psophocarpus tetragonolobus	Winged Bean	P/A	4.3-6.8	70-410	23-32	Sdw,Tvw
Punica granatum	Pomegranate	P	4.3-8.3	30-420	13-27	Wtm,Tvw
Saccharum officinarum	Sugarcane	P	4.3-8.3	50-420	16-27	Wdm,Tvw
Sechium edule	Chayote	P	5.2-8.0	50-260	15-27	Wdw,Tdm
Simmondsia chinensis	Jojoba	P	7.3-8.2	20-30	17-20	Wt,Td

Table 1.2: Maximum ecological tolerances for some tropical crops.

Scientific name	Common name	Length[1]	pH	Rainfall (cm)	Temp range (°C)[2]	Life Zones[3]
Solanum melongena	Eggplant	P/A	4.3-8.3	20-420	7-27	Csw,Txw
Solanum quitoense	Naranjilla	P/A	5.8-8.0	70-310	11-25	Cw,Smw
Solanum tuberosum	Potato	P/A	4.3-8.3	30-460	4-27	Bmw,Tvw
Sorghum bicolor	Sorghum	P/A	4.5-8.3	40-310	8-27	Csw,Ttw
Syzygium aromaticum	Clove	P	6.8-7.3	70-400	24-26	Sd,Tm
Tamarindus indica	Tamarind	P	4.3-8.0	60-420	20-29	Sdw,Tvw
Telfaria pedata	Oyster Nut	P	5.7-8.0	80-250	19-27	Sm,Td
Theobroma cacao	Cacao	P	4.3-7.4	70-420	18-28	Sdw,Tdw
Vanilla planifolia	Vanilla	P	4.3-8.0	70-420	19-28	Sdw,Tmv
Vigna radiata	Mung Bean	A	4.3-8.3	40-410	8-27	Cm,Ttw
Vigna unguiculata	Cowpea	A	4.3-8.3	30-410	13-27	Wtm,Ttw
Vigna unguiculata	Yardlong Bean	A	5.5-7.3	70-280	16-27	Wdm,Tdm
Vigna unguiculata	Catjang Cowpea	A	5.6-6.0	150-170	17-23	Wdm,Td
Vitis vinifera	Grape	P	4.3-8.6	50-330	7-27	Cmv,Tvw
Zea mays	Corn	A	4.3-8.3	30-400	5-29	Bmw,Txw

[1] Life length: A = annual; B = biennial; P = perennial; P/A = perennial grown as an annual; B/A = biennial grown as an annual.

[2] Annual temperature range in a zone where the crop is grown. The optimal temperature range for crop growth is between the extremes. Annual crops that would not survive winter temperatures are grown in the summer.

[3] See Table 1.1 for abbreviations.

Table 1.3: Suggested crops for specific climatic zones.

GRAINS	LEGUMES	VEGETABLES	FRUITS	OTHER
HOT HUMID TROPICS (LONG RAINY SEASON, NO COOL WEATHER)				
PADDY RICE	WINGED BEAN	ARROWROOT	BANANA & PLANTAIN	BLACK PEPPER
		DASHEEN	BREADFRUIT	CACAO
		PUMPKIN	JACKFRUIT	OIL PALM
		SWEET POTATO	PEACH PALM	OTHER SPICES
		TARO		
		YAM (ASIAN)		
TROPICAL MONSOON (STRONGLY ALTERNATING WET AND DRY SEASONS)				
CORN	COWPEA	ARROWROOT	AVOCADO	CACAO
PADDY RICE	PEANUT	DASHEENS	BANANA & PLANTAIN	COCONUT
SORGHUM	PIGEON PEA	EGGPLANT	BREADFRUIT	COFFEE
UPLAND RICE	SOYBEAN	OKRA	CACAO	OIL PALM
	WINGED BEAN	PEPPER	CITRUS	SUGAR CANE
	YARDLONG BEAN	PUMPKIN	GUAVA	
		SWEET CORN	JACKFRUIT	

Table 1.3: Suggested crops for specific climatic zones.

GRAINS	LEGUMES	VEGETABLES	FRUITS	OTHER
		SWEET POTATO	MACADAMIA NUT	
		TOMATO	MAMEY SAPOTE	
		YAMS	MANGO	
			MANGOSTEEN	
			PAPAYA	
			PASSION FRUIT	
			PINEAPPLE	
			SOURSOP	
DRY TROPICS (A LONG, HOT DRY SEASON WITH A SHORT OR IRREGULAR RAINY SEASON)				
AMARANTH	COWPEA	CANTATLOUPE	AVOCADO	SISAL
CORN	LABLAB BEAN	CASSAVA	BREADFRUIT	COTTON
MILLET	MUNG BEAN	CUCUMBER	CITRUS	
SORGHUM	PEANUT	EGGPLANT	GUAVA	
UPLAND RICE	PIGEON PEA	OKRA	MAMEY SAPOTE	
	SOYBEAN	ONION	MANGO	
	YARDLONG BEAN	PEPPER	PAPAYA	
		PUMPKIN	PASSION FRUIT	
		SWEET CORN	SUGAR APPLE	
		SWEET POTATO	TAMARIND	
		TOMATO		
		WATERMELON		
HIGHLAND CLIMATE, DRY AND COOL				
AMARANTH	CHICKPEA	BEET	AVOCADO	
MILLET	COMMON BEAN	CARROT	FIG	
QUINOA		COOL SEASON VEG'S	PAPAYA	
SORGHUM		LEEKS	PERSIMMON	
		LETTUCE	WHITE SAPOTE	
		ONIONS		
		SWEET POTATO		
HIGHLAND CLIMATE, WET AND COOL				
CORN	CHICKPEA	BEET	AVOCADO	COFFEE
	SCARLET RUNNER BEAN	CARROT	PERSIMMON	
		CHAYOTE	PAPAYA	
		COOL SEASON VEG'S	PASSION FRUIT	
		LEEKS		
		LETTUCE		
		ONIONS		
		SWEET POTATO		