

Weather Volatility: Better Understanding the Challenges Faced by Small-holder Millet Farmers in the Kolli Hills of India

World Food Prize 2013 Borlaug-Ruan Intern Report

By Mark Gee from Johnston, Iowa

“Three-quarters of the world’s poorest people get their food and income by farming small plots of land. So if we can make those small-holder farmers more productive and have more profit, we can have a dramatic impact on hunger and nutrition and poverty. Melinda and I believe that helping the poorest small-holder farmers grow more crops and get them to market is the world’s single-most powerful lever for reducing hunger and poverty.”

Bill Gates, Speech at the World Food Prize in 2009 in Des Moines, Iowa

Purpose of this report

The purpose of this World Food Prize Borlaug-Ruan report about my eight-week internship at the M.S. Swaminathan Research Foundation in India is to encourage fellow students to:

- * Take a holistic, global, long-term approach to agriculture that considers both small-holder and big-holder farmers.
- * Learn from the knowledge and experience of M.S. Swaminathan, Norman Borlaug, Bill Gates, Howard Buffett and others.
- * Not take things for granted especially food, soil, water, and climate.
- * Appreciate the practicality, local knowledge and hard work of small-holder farmers, the daily challenges they face and what they accomplish with the resources they have.
- * Carefully evaluate what is being promoted to them, by whom and why.
- * Do what they can to help small-holder farmers help themselves.
- * Be interns through the World Food Prize and other organizations.

	Page
Table of Contents	
Purpose of this Report	1
Holistic Approach to Agriculture – M.S. Swaminathan, Norman Borlaug, Bill Gates and Howard Buffet	2
Small-holder Farmers, Weather Volatility and My Interest	5
Research: Field Interviews and Four Lab Experiments	6
Field Interviews – Learning from Farmers	8
Soil Quality Experiments– Studying Helpful Bacteria	12
Plant Genetic Diversity Experiment – Finger Millet	13
Challenges Millet Farmers Face Concerning Weather Volatility	14
Ways to Help Millet Farmers of the Kolli Hills Help Themselves	15
Impact of Research Project	17
Lessons I Learned / Re-learned	18
Suggestions for Future Interns	21
Appreciation	22
Citations	25
Pictures	26

This report is written for high school and college students who want to be interns at agricultural research stations through the World Food Prize and other organizations. Even though there is no unique information in this report nor is my research scientifically valid, my hope is that fellow students will benefit from my experience, be better interns and make the World a better place.

This report makes the following assumptions:

- * There will be, to some degree, an increase in volatile weather events.
- * Millet is an important crop that should be protected incase it is needed to adapt to weather volatility.
- * Millet farmers in the Kolli Hills want help.

My thinking will continue to evolve over time but I consider this report to be the capstone project of my High School education because it consolidates what I learned from the internship at the MSSRF, World Food Prize Symposium Speeches over the years, growing vegetables, independent reading and other experiences. Writing this report has helped me clarify my thinking on a range of subjects. I am very appreciative of the many people who made this opportunity possible.

The personal highlight of my internship in India was conversing with Dr. Swaminathan about a range of topics during tea, at his office, during dinner at his home with his wife, the opening of a new research facility and his 88th Birthday Party which the President of India attended. Before returning home, Dr. Swaminathan also asked me to present about my project at a weekly seminar of researchers at the MSSRF in Chennai.

In Iowa, two months later at the World Food Prize Global Youth Institute, I was honored that Dr. Swaminathan; Dr. Ejeta, World Food Prize Laureate in 2009; Amb. Quinn, President of the World Food Prize Foundation; and, Dr. Lumpkin, Director General of CIMMYT in Mexico; Keegan Kautzky, Director of National Education Programs for the World Food Prize; and my family were able to attend my presentation about my internship at the MSSRF.

My experiences at the M.S. Swaminathan Research Foundation, gave me a first-hand understanding of Dr. Swaminathan's holistic approach.

Holistic Approach to Agriculture – M.S. Swaminathan, Norman Borlaug, Bill Gates and Howard Buffet

To face the challenges confronting agriculture, including weather volatility, there is no single “right” answer, person, organization or business but, in my opinion, there is a generally right approach. I think, M.S. Swaminathan, Norman Borlaug, Bill Gates and Howard Buffet, among others, are telling us a way if we will listen and take action.

It is important to pay close attention to these four people in particular, among others, because:

M.S. Swaminathan is one of the most renowned living expert in global agriculture for several reasons. First, he has incomparable years of experience. He was born in 1925 and therefore knows the world well before the Green Revolution when India required massive shipments of grain to avoid famine. He was influenced by Mahatma Gandhi in his youth and was 22 years old when Gandhi was assassinated in 1948. In the 1960's, he personally invited Norman Borlaug to India and the country's agricultural production significantly increased in two years though classic Green Revolution methods. This was a significant achievement in an incredibly short period of time but, as some negative consequences of some Green Revolution techniques became apparent in subsequent years, Dr. Swaminathan adapted this thinking and began striving to “improve productivity in perpetuity without associated ecological and/or social harm” as described in his book “From Green to Evergreen Revolution.” Dr. Borlaug also recognized the negative consequences of some Green Revolution techniques and spoke about them in his Nobel Prize Acceptance Speech. Dr. Swaminathan is a fellow of the U.S. National Academy of Sciences, Royal Society of London, the Russian Academy of Sciences, the Chinese Academy of Sciences, and the Italian Academy of Sciences. Many people have never heard of Dr. Swaminathan but he can pick up the phone and any leader in the world who knows anything about agriculture will take his call.

Because of my experience at the MSSRF this summer, I now know why Dr. Borlaug and so many others regard Dr. Swaminathan so highly. Dr. Swaminathan was selected as the very first World Food Prize Laureate in 1987. He used the award funds that accompanied being named a Laureate to establish the M.S. Swaminathan Research Foundation in India, in 1988. The foundation is part of Dr. Swaminathan's effort to move beyond talking and to make progress that actually helps people.

Norman Borlaug's accomplishments are many. He is one of only seven people to be awarded the Nobel Peace Prize (1970), US Presidential Medal of Freedom, and Congressional Gold Medal. The native of Iowa, who passed away in 2009 at the age of 95, is best known as the "Father of the Green Revolution" for developing wheat varieties that were resistant to rust disease and that responded very well to fertilizer. A key reason Dr. Borlaug was able to develop these varieties of wheat is because in the 1940s he went against conventional wisdom and started a shuttle breeding program between two locations in Mexico 700 miles apart which gave him two growing seasons per year. Before Norman Borlaug, it was thought that seeds needed a rest period to gather the energy to germinate. The world is a better place because of Dr. Borlaug's effort to serve the common good in agriculture.

Bill Gates is astute at whatever he sets his mind to including programming, business, family and taking on tough challenges in the world like agricultural development and other issues through the Bill and Melinda Gates Foundation.

Howard Buffet is an independent farmer with the resources to not be beholden to any special interest. As he said in his keynote address at the World Food Prize Symposium in 2011, "Farming, Philanthropy and Failure: Lessons about Small Farmers and Feeding the World," Howard Buffet tells it like he sees it, announces when he "screws up," then makes improvements. Because he farms land in the United States, Africa and other countries, personally conducts on-farm research, and has travelled to over 100 countries and spoken to hundreds of farmers, he has a unique perspective concerning farmers and agriculture. He and his son have given themselves a deadline of 40 years to put more than \$3 billion to work to help the most vulnerable people on earth who lack food security, many of whom are small-holder farmers.

Based on their publications and speeches at the World Food Prize Symposium, these diverse people with different backgrounds, educations, professions and life experiences, in my opinion, generally concur about **what** needs to be done in agriculture to improve the World. The **how** is what we need to figure out.

Unless I find something better, the mission statement of Dr. Swaminathan's Research Foundation (MSSRF) effectively sums up an effective holistic approach to agriculture:

"MSSRF has all along been developing and following a pro-nature, pro-poor, pro-women and pro-sustainable on-farm and non-farm livelihoods through appropriate ecotechnology and knowledge empowerment." (www.mssrf.org)

Pro-nature. Through trial and error over millennia, nature has developed ingenious solutions to problems like repelling pests, suppressing weeds and building soil. These methods are not perfect, but they have proven themselves over the long term in diverse circumstances. Emulating nature's solutions can help increase food security in a sustainable way.

Pro-poor. The poor are the ones who are hungry. They do not have access or the means to buy food. Any effort to eliminate hunger that does not focus on the poor won't work.

Pro-women. Male dominated society has had its chance to eliminate hunger and failed much of the time and in many regards. Women do much of the work of small-holder farms and feeding families. However, they have been systematically left out of decision making and excluded from education. We need to utilize everybody's potential.

Pro-sustainable. This applies to farming and the techniques used to increase yield but also to non-profits and their work to help the poor. For example, outside assistance can't be carried on forever, so the MSSRF is working to help farmers in India develop community self-help groups.

On-farm and non-farm livelihoods. Developing farm livelihoods obviously plays an important role in reducing hunger. If farmers can't make a living producing food, what incentive is there? Food and hunger issues are not limited to the farm. Many hungry people are concentrated in urban slums. If these people do not have a way to make a living, then how can they buy food and support farmer's livelihoods? Producers and consumers are intricately connected and efforts that ignore one side will eventually fail.

Appropriate ecotechnology. Every technology is not applicable in every location. Howard Buffet has talked about how he has seen highly productive corn breeds meant for rich Iowa soils can deplete nutrients and cause crop failures in poor African soils. New technologies that are implemented need to be right for local ecosystems. Ecotechnology, especially genetically modified organisms (GMOs) can be a sensitive issue but as Amb. Quinn, President of the World Food Prize Foundation said at the 2013 Symposium, "We have to preserve and sustain the great gifts we have in our land, water and plants and at the same time, we have to use science to multiply the harvest."

Knowledge empowerment. Knowledge is the key for progress. Sharing best practices from around the globe can help everyone improve. Often, the only thing separating people from slash and burn agriculture and sustainable cultivation is a lack of knowledge about better techniques. Knowledge about weather predictions can help farmers protect their farm and knowledge of markets can help them get a fair price for their crop. With knowledge, people can make educated decisions to improve their lives.

The accomplishments of the MSSRF are many, but like all organizations, the MSSRF has the constant challenge of consistently implementing its approach though out the organization and delivering results over time. The MSSRF has had notable success in its efforts to:

- Increase the access of rural women to land, irrigation water, technology, credit, insurance and markets.
- Facilitate the formation of self-help groups to improve livelihoods by making specialty products from crops to be sold in organic shops in cities.
- Partner with farmers in starting and managing community projects then tapering external support rather than just doing and delivering projects.
- Educate farmers about the importance of biodiversity, genetics, nutrition and more.
- Conserve biodiversity among millet, rice, mangroves and other plants through promoting on farm conservation and gene banks.
- Help farmers exercise their legal rights to the biodiversity they conserve.
- Conserve and rebuild costal wetlands and mangrove forests.

As speakers have said at the World Food Prize Symposium over the years, we basically know what needs to be done in agriculture – sustainably produce more food and get it to the people who need it – so there is no need to spend excessive time, money and effort talking among ourselves about what needs to be done.

The answer to the question of Why? Because it is needed. When? Now. Where? Make progress everywhere we can.

We need to focus on the question – How is this going to be done and by whom? Agriculture is so vast and complex that no one can do it all. Priorities need to be set and as many capable people as possible need to choose an area in which they have ability, get started now, advance and make adjustments along the way. This is being done to a degree but more people need to do more at all levels – individuals, non-profits, business and government.

The work ahead is much like what farmers have faced over the centuries – thoughtful, patient, hard, risky, hopeful and never-ending labor. All we can do is die trying like Norman Borlaug, Henry A. Wallace, and many others have done before us.

Small-holder Farmers, Weather Volatility and My Interest

“Less developed countries are expected to have less capacity for adapting to climate change and thus, even in the short-term, there are likely to be significant effects on global hunger and well-being.” USDA report “Climate Change and Agriculture in the United States”

Farmers have always dealt with weather volatility, but there is evidence that the intensity and frequency of extreme weather events is increasing and that what has been done in the past might not be adequate for the future. Therefore, there is a need to better understand the challenges faced by all farmers and reevaluate in order to better prepare for, mitigate and recover from weather volatility.

To be consistently productive, farmers throughout the world need a certain level of stability. Even if a growing season is just a few months, if it is always about the same months, rainfall, temperature and other factors, decisions can be made based on historical expectations which results in higher productivity. We can have excellent soil, seed and other inputs, but if the weather surpasses certain thresholds, crops can be wiped out in a very short time.

I think of weather volatility as a consequence of the much more complicated scientific and political issue of climate change. This report focuses on weather volatility because most people, including the farmers I interviewed in India, think in terms volatile weather since it is something we all see – flood, drought, heat, cold and wind – much more clearly than the multifaceted, longer-term, impacted-by-humans concept of climate change.

What makes weather volatility so challenging is that it further complicates the already complicated interactions of rain, sunlight, weeds, disease, insect pests, pollinators, erosion, soil quality, plant diversity and more. Moreover, preparing only for less rain and more heat does not guarantee success because the opposite could happen in some places.

This is an important issue because, as Jeffery Sachs, Director of the Earth Institute at Columbia University, said in his keynote address at the World Food Prize Symposium in 2009, “We have a world of climate shocks that clearly is a change of state of the world, not simply a run of bad luck. And when these shocks occur, they of course have remarkably acute effects on the world economy now because of the interconnected global food system.”

Dr. Sachs went on to explain beyond a doubt that we are failing to make progress in climate change and many other key areas – global hunger, malnutrition, obesity, micronutrient deficiencies, higher food prices globally, conservation, water stress, population growth, and more. “I think we are at a graver challenge on food than we’ve been at for many decades and why the challenge is even more complicated now than perhaps it was at what was certainly an urgent time at the start of the Green Revolution.” It has been years since Dr. Sachs gave this speech in 2009 at the World Food Prize Symposium and we are still not making much progress.

If extreme weather events increase, there could be significant consequences for everyone, but especially for small-holder farmers. To make matters worse, small-holder farmers in developing countries seem to have the least resources and interest in preparing for the possible increase in intensity and frequency of extreme weather events. But this does not have to be the future.

Small-holder farmers are important because as Bill Gates said in his speech at the World Food Prize in 2009, “Three-quarters of the world’s poorest people get their food and income by farming small plots of land. So if we can make those small-holder farmers more productive and have more profit, we can have a dramatic impact on hunger and nutrition and poverty. Melinda and I believe that helping the poorest small-holder farmers grow more crops and get them to market is the world’s single-most powerful lever for reducing hunger and poverty.”

My interest in small-holder farmers, evaluating traditional practices, and climate change is an extension of my interest in plants, insects, soil, water, science and engineering. I have grown a garden with my family for as long as I can remember. In 2008, I started a small business with my younger brother growing vegetables and selling at local farmers' markets. The income has never been much but the learning has always been high. In 2006 when I was 10, I had the opportunity to meet Dr. Borlaug and have gone to the World Food Prize every year since. I participated in the Global Youth Institute in 2010 and was placed at the M.S. Swaminathan Institute in India in 2013 as a Borlaug Ruan Intern. I graduated from Central Academy in Des Moines and Johnston High School in May 2013. Practical experience with plants and agriculture helped me connect with farmers in the Kolli Hills, India and elsewhere.

Before going to Purdue University in the fall of 2014 as a Beering Scholar, I am taking a bridge year to travel and study agriculture first-hand in India and Mexico. In India, I was at Dr. M.S. Swaminathan's Research Foundation for eight weeks in the summer of 2013. I will be in Mexico from January through May in 2014 at the International Maize and Wheat Improvement Center near Mexico City which is commonly called CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo). This is where Dr. Borlaug did much of his research and where he learned about winning the Nobel Peace Prize in 1970 while working in a crop field.

At Purdue, I plan to study broadly and pursue a triple major – agronomy, biochemistry and engineering in five years then start a PhD in something specific. I am traveling now before college because what I am experiencing will help me better filter, understand and apply what I learn in college.

Research: Field Interviews and Four Lab Experiments

For my research, I wanted to do a project on my own that related to my interests in small-holder farmers, evaluating traditional farming practices, and weather volatility.

I connected my interests by conducting 20 field interviews with small-holder farmers to better understand how they make decisions about their farming practices because their practices are what affect their preparation for weather volatility. To gain experience in evaluating the impact of traditional farming practices, I did four trial experiments – three concerning helpful bacteria in soil and one about the genetic diversity of millet. Soil quality and plant genetic diversity are key factors in dealing with weather volatility.

My project fit well at the MSSRF because their approach to agriculture is so holistic and practical. The main ways my project fit into the overall work of the MSSRF were:

Pro-nature. Finding inherent strengths in soil and plants, such as millet, that can be nurtured so that plants are more resilient to weather volatility. As well, better understanding how farmers viewed soil, water and other natural resources can help promote conservation.

Pro-sustainable. Looking for ways to adapt to weather volatility for the long term.

Appropriate ecotechnology. Working with MSSRF scientists to develop ecotechnologies that could hopefully help farmers adapt to weather volatility.

Pro-poor. Helping the poor grow more millet especially in the face of weather volatility.

The Kolli Hills is an interesting place to study weather volatility because the hills create various micro-climates with different rain patterns, temperatures and weather. Farmers in different micro-climates have had to deal with different problems and have developed a range of adaption strategies.

According to the Indian Network for Climate Change Assessment (INCCA), climate change predictions for the Kolli Hills region include:

- Monsoon drought weeks increasing by 20-50%.
- Number of rainy days decreasing by 1-5 days per year.
- Intensity of rain increasing between 1 to 4 mm/day.
- Annual air temperatures increasing from 28.7 ± 0.6 °C to 29.3 ± 0.7 °C.
- Minimum temperatures increasing by about +3.5 °C.
- Maximum temperatures increasing by about +1 °C.

The crop I focused on in the Kolli Hills was millet because it is an underutilized crop with high potential that is most often grown by poor farmers. Dr. Gebisa Ejeta, a professor at Purdue and World Food Prize Laureate in 2009, is the person who first got me interested in underutilized crops because of his work developing drought and pest tolerant sorghum.

Millet is a small grain which is typically ground into flour and mixed with water and spices and/or sugar to make porridge, dense cakes, flat breads, drinks and many other items. Through selection over generations, there are currently about 10 major varieties of millet in the Kolli Hills. Within each major variety, there can be several distinct types. It is a highly nutritious crop that requires minimal inputs and has very few natural pests, but due to its taste it is typically only grown by poor farmers and is ignored by most researchers in favor of more popular grains, especially rice. It is possible that the taste of millet and social stigma as a grain of the poor could be mitigated by developing other ways to eat it like George Washington Carver did with peanuts. The MSSRF has published booklets about different ways to cook millet.

Because my research was interdisciplinary, several people in different areas helped me. Before I left Iowa for India, I met with Dr. Jerry Hatfield at the USDA research laboratory located at Iowa State University. He was the lead author of the USDA report “Climate Change and Agriculture in the United States: Effects and Adaptation.” At the MSSRF in Chennai, Dr. Nambi, who was the lead scientist on climate change, helped refine my farmer interview questions. For my lab experiments with soil and genetic diversity of finger millet, Dr. Raji’s Biotechnology Group and specifically Ganesh Govindhan taught me many lab techniques. In the Kolli Hills, Dr. King who coordinates millet projects with farmers was my mentor.

I have experience growing vegetables, visiting with farmers and doing lab work in the United States, but my eight weeks in India were truly experimental – trying things and seeing what happened. My research was always in a state of flux, and should have been, because of new observations, ideas and experiences.

I very much appreciate Dr. Swaminathan and my mentors at the MSSRF for giving me the freedom and responsibility to think of, develop, adjust and carry out my own project. Working on my own and learning from my mistakes is how I learn best.

Field Interviews – Learning from Farmers

The Kolli Hills is an area of about 100 square miles in the Southern part of the state Tamil Nadu, India. For at least the past five centuries, the hills have been inhabited by a tribal group called the “Malayali Grounders” who make their living from farming. They clear portions of the forest through slash and burn techniques to cultivate crops.

The farmers I interviewed in the Kolli Hills were very nice, patient and generous.

Interview Purpose and Process

Assuming that there will be some degree of increased weather volatility in the Kolli Hills and that farmers can be helped to prepare, the goals of the interviews were to:

1. Identify whether existing farming practices were resilient to increased weather volatility.
2. Learn what farmers knew about weather volatility and what they were doing to prepare.
3. Determine ways to help farmers better prepare themselves for weather volatility.

To interview the millet farmers, I created what I considered to be an impressive questionnaire that covered the millet farming system, major factors affecting adaptation and more. As a resource, I used the report “Climate Change and Agriculture in the United States: Effects and Adaptation” and its suggestions for future research.

The first questionnaire was 78 questions and nine pages. After two hours with the first farmer, we were still only 2/3 finished. The patient man finally said he had to get back to farming and left quickly. Not to be deterred, I found another farmer to interview that evening. It was raining so it was an ideal time to talk since he could not be in the field. He invited me to have dinner with his family in their hut. Again after about two hours and only 2/3 finished, he said “Let’s talk about other things” so we did.

I then reduced the questionnaire to 55 questions that I could get through in about 45 minutes which was about right for the time the farmers had for me.

Of the twenty millet farmers interviewed, seven were female and thirteen were male. They ranged in age from 30 to 75 years old with a mean age of 50. All farmers were married and the mean household size was 4.2 people. Concerning education, the female farmers were more likely to have attended school. However, the women who went to school completed a mean of only 5.8 grades and the men who went to school completed a mean of 7.6 grades. The mean farm size was 3.0 acres but 47% of the farmers owned two or less acres. Every millet farmer also grew other crops.

After the interviews were finished, I read through all of the surveys to get a feel for the common answers. I created an excel spreadsheet to categorize the answers to each question and analyze the data numerically. For each question of the survey, I created a set of standard categories and sorted the respondents’ answers among them or labeled the response as “other.”

Even though I did not speak their language and had to use a translator, I learned a lot from the farmers in the Kolli Hills. However, my field interviews were not statistically valid for several reasons:

* Farmers were chosen based on availability. A village was chosen by my translator and he would take me there on a motorcycle which was a lot of fun with the hilly roads. There were times when the roads were so washed out that we got off the motorcycle and walked.

My translator and I would walk around to look for millet farmers. He would ask in Tamil if they had time to speak and I would look as friendly as possible. We made an effort to include both genders and multiple age groups. However, it is possible that I talked with farmers who were more social, took more breaks, liked foreigners or have other characteristics that made them more available. As well, a religious head man and a farmer who no longer grows millet were specifically sought out for interviews.

* I only conducted 20 in-depth interviews. Of these, not every farmer answered every question.

* Some farmers interviewed were influenced by family members and friends who watched the interview. During one interview with a woman, her father sat directly in-between me and her then began talking for his daughter. She became quiet and did not answer any more questions.

* The interview questions evolved as I learned more and made improvements.

Because the field interviews are not statistically valid, I describe trends in this report but do not quote specific numbers from the compiled interview results. There are many types of farmers in the Kolli Hills and it is important to keep in mind that my observations are mainly about the 20 millet farmers I interviewed, not all farmers in the area. The information below is based on interviews with those 20 farmers, observations in the field, reading and talking with experts.

Millet and Other Crops

The millet farmers interviewed said they grow millet because it is nutritious, wards off disease, prevents diabetes and helps new mothers lactate. Farmers typically store enough millet in their home for their families to eat during the year and to plant the next season. Any surplus is sold to have money to buy goods and government subsidized food.

Farmers choose their millet variety primarily based on tradition and saving seed from previous years. A few grow “High Yielding Varieties” promoted by the MSSRF and all of those farmers had completed 8 years of school, which is much more than average. Most farmers said they had the money to buy “High Yielding Varieties” but the seeds are not worth the cost.

All the millet farmers also grew other crops. Mixed cropping is done by about half of the farmers and consists of mixing millet (Italian, Foxtail, Little, Proso, and Pearl), beans, maize, mustard and other crops grown in the same field at the same time. The other half of millet farmers would keep each crop in a separate area. Cassava (root is used to make tapioca), rice, bananas and coffee are also commonly grown.

Farming Practices

The Kolli Hills is influenced by a mix of traditional, Evergreen Revolution and some classic Green Revolution farming practices. While there, I helped farmers weed, plow and plant millet through broadcast seeding and by planting in rows. Like people everywhere, each farmer had their own unique ways of doing things but there were similarities.

All the farmers till their land before planting, generally in May or June. Millet is planted in July or August with the onset of the monsoon and is harvested in November and December. Before the millet is ready to harvest, most farmers plant beans underneath which sprout and grow a small amount. Once the millet is harvested, the beans take over the field. After the beans are harvested, the land is left fallow for about 4 months before planting millet again when the monsoon starts.

Many farmers use practices that could be classified as traditional or Evergreen such as mixed cropping, crop rotations, applying manure and more. Some of the farmers say they are doing a practice because of what they learned from the MSSRF, but others will say they are doing it because that is what their forefathers did in such situations. Both groups are attributing the effective practice to different sources – the MSSRF or tradition. The difference between traditional and Evergreen practices is that Evergreen methods have a rational other than tradition.

The term “traditional farming” can be misused as a catch all term to justify whatever a farmer wants to do. In the past, farmers have planted millet by throwing seed across the field and raking dirt over it. Once the millet sprouts, a plow is taken across the field to reduce the number of millet plants. The MSSRF has been promoting sowing millet in rows. It takes more work at the beginning to plow the rows and seed them accurately, but it increases yields and reduces work overall because farmers do not have to kill the extra millet plants. However, there is some resistance to this because farmers don’t like that it requires more work up front so they say they want to stick with “tradition.” One farmer I spoke with planted in both ways – some of his millet would be planted in rows because the MSSRF pays farmers to try the new technique, and some of his millet would be broadcast seeded because that is what his father did and that is what he likes to do.

Classic Green Revolution practices are not yet widespread but they are increasing. Recently in the Kolli Hills, roads have been built as part of the government's development program which has improved access to markets. This has also increased the availability of chemical inputs and their use is increasing.

Increased connection to markets has advantages. Farmers are growing more cash crops and use the money to buy goods and subsidized rice from the government sponsored Public Distribution System. However, this has led to a decrease in diet variation because previously the farmers grew a greater variety of crops to eat than what they buy from the Public Distribution System. Only farmers with land at the bottom of hills grow rice because that is where water and the best soils are located.

As millet farmers switch to cash crops such as cassava, pineapple, coffee and pepper and grow them year after year in the same field, soil quality decreases and locally-adapted millet varieties are abandoned. The loss of local millet varieties is significant because local varieties contain genes that increase adaptation to a wide range of conditions. If the genes are lost, plant breeders will no longer be able to use the genes to develop improved crops. The MSSRF has established programs to support farmers who conserve millet varieties on their farm and preserved some varieties in a seed bank.

Soil of the Kolli Hills

As the name would suggest, the Kolli Hills is a region with a lot of slope and terracing with stone walls is generally done by farmers to hold soil back.

The majority of millet farmers I spoke with say their soil quality has declined over the past years. Some said there has been no change. No farmers said their soil quality increased. The decline in quality was attributed to erosion; mono-cropping of cash crops, especially cassava, for several years in a row in the same field; and, low manure application due to a loss of ownership of cows.

Cow manure is used by the great majority of farmers to augment soil fertility. Chemical fertilizers are used by about a quarter of the millet farmers and a few of the farmers I interviewed compost. Some farmers stated problems with using chemical fertilizers including disease-like effects and lodging of crops. One farmer mentioned that he thinks that the use of fertilizer killed the worms in his soil. Some farmers I spoke with said they could not grow cover crops or compost because there was not enough water.

Mechanization

The great majority of millet farmers I spoke with rely on cows to plow fields and hand labor with simple tools to weed and harvest. Other than vehicles, I saw only three pieces of mechanized equipment used by small holder farmers in the Kolli Hills – a mechanized grain grinder, a plow for rice paddy fields that was in front of a home and a small red tractor in the distance plowing a field. The farmer I was interviewing said that the small red tractor cost 450 rupees an hour to rent compared to a field worker who makes less than 15 rupees an hour. Farmers rent tractors for plowing for three main reasons:

- Many had gotten rid of their cows because it is time consuming to keep cows trained for effective plowing and expensive to care for them year round.
- They had a hard time finding people work in their fields.
- Even if workers could be found, the tractor was more reliable and faster.

I never saw people renting cows for plowing but it seems like a logical thing that would exist.

On land owned by a wealthy city dweller, I saw a yellow backhoe being used to rip out trees to clear land for farming in tandem with a red tractor.

Social Influences on Adapting to Weather Volatility

Power to make decisions is clearly tilted towards the males in the households. About half of the farmers I interviewed said the male makes decisions about the farm and the other half said it was a joint decision between the male and female. Only one household was lead by the female and that was because the husband had died and there were no children living at home. About half of the women interviewed said the decisions were made jointly, but only a third of the men said so. This could have been due to a desire by men to meet a social norm of male dominance or it could have been because women who were able to be interviewed had a better position in the home.

Religion affects farming in the Kolli Hills through the “headman system.” A religious headman, who is hereditarily determined, is supposed to be the first person to plow and the first person to plant in each village. After he has plowed, the villagers are free to do so and the villagers can plant after he has planted his fields. This system could be enforced with social and financial penalties, but no one interviewed had ever heard of someone disobeying.

This makes the religious headman key to the ability of millet farmers to adapt. The headman interviewed said that he chooses his planting date mainly on weather suitability, not for religious reasons. The dates he chooses are very early so that the whole village has a reasonable amount of time to complete the work.

The MSSRF has a large influence on millet farmers through the combined impact of its seed development program, spreading improved farming practices and teaching farmers how to produce products from millet that are sold in organic shops in local cities. Due to this work, farmers see the demand for millets to be increasing and most think millets are profitable. The MSSRF is in a position to help farmers understand and adapt to weather volatility as it is already trying to do.

Farmer Perceptions of Weather Volatility

I asked the millet farmers what predictions they had heard about weather volatility and where those predictions came from. The most common predictions mentioned were less water, impending famine, hotter temperatures, less yield, and unseasonable rain. The farmers said this information came primarily from elders and other farmers. The MSSRF has set up Village Resource Centers with staff members and internet connections to help spread information.

Almost all millet farmers I interviewed say they are already experiencing more drought and many said temperatures had increased in the past few years. No one said that there was more rain or that temperatures had decreased, but that could be because the region was suffering from drought when the surveys were taken. Eighteen of the twenty farmers I interviewed believed that the observed changes were part of a long term change in their environment. The other two farmers believed the changes were due to natural variation in weather. The two farmers had attended school twice as long as the other farmers interviewed.

About half of the farmers interviewed said weeding had increased over the past few years, although most of those farmers attributed the increase in weeds to manure application bringing in seeds, not weather volatility. A shift in weed species has been noticed by the farmers. A third say they have seen new types of weed species in the past few years. When asked which types, grasses were especially noted to have increased. Climate scientists have predicted that grassy weeds would become more competitive as CO₂ levels increased in the atmosphere.

Farmer Strategies for Adapting to Weather Volatility

When asked how they dealt with extreme weather events in the past, which was mainly drought because they live and farm at the top of hills, farmers said migrating to find wage labor, leaving some land fallow,

adjusting planting dates, living on government drought relief, eating previous year's crop, and using water catchment structures.

When asked about dealing with increased weather volatility in the future, most of the millet farmers said they plan to continue what they have done in the past. Others said they would also cautiously consider growing cassava or perennial cash crops such as coffee and black pepper; digging a well for irrigation; and increasing how much they plant of crops that do well.

The millet farmers interviewed mentioned a wide array of responses for what they would do if changing weather patterns caused a new pest to migrate to the area including applying a chemical or wood ash as a pesticide, waiting out the pest, switching variety of millet and changing crops.

Soil Quality Experiments – Studying Helpful Bacteria

Soil health is the foundation of any agriculture system, and soil microbes are essential to healthy soil. As Howard Buffet said in his keynote address at the 2011 World Food Prize, “If the soil is ‘dead,’ void of biological activity, synthetic nitrogen will not help. It is like saying that you can put an oxygen mask on a cadaver and revive the person.”

The MSSRF has an ongoing program to study soil bacteria. Researchers are searching for a microbe that can be applied to fields in order to help plants grow and to suppress pests. They have a variety of screening procedures to identify and vet candidate microbes.

I did three experiments on soil bacteria as a way of indicating soil health in the Kolli Hills.

Soil Experiment 1 of 3: Number of bacteria

There are tens of thousands of bacteria types in the soil, and only a small fraction can be grown in the lab. Scientists use the number of bacteria colonies they can get to grow in a lab as an estimate of how many bacteria were in the soil originally. This technique is called determining the number of colony forming units (CFU).

The calculated CFU values for the soil samples from the Kolli Hills were lower than expected. Fewer colony forming units were identified compared tests on surrounding regions done by MSSRF staff. This could indicate poor soil health. However, soil bacteria are in a constant state of change. The number of bacteria at any one time depends on rain, temperature and many other factors. The time from collection to analysis can affect results. More tests should be done over a range of conditions to get a conclusive result.

Soil Experiment 2 of 3: Screening for fungus suppression

The total number of bacteria in the soil is interesting, but the quality of those bacteria is really what is important. Bacteria from the K-3 sample were tested for suppression of the plant fungus *Fusarium oxysporum*. If the soil bacteria can suppress this pest, they can help reduce plant stress and possibly help plants adapt to new pests that migrate due to climate change.

Of the 24 bacteria screened, two clearly suppressed the growth of *Fusarium oxysporum*. Six other bacteria seemed to suppress *Fusarium oxysporum*, but it is uncertain which bacteria caused the suppression or if it was due to teamwork between bacteria types. This shows that some of the bacteria in the Kolli Hills can help suppress plant pests.

Soil Experiment 3 of 3: Screening for Plant Promotion

Bacteria can promote plant growth through many ways. One common method is through the production of the hormone Indoleacetic acid (IAA). Rhizomal bacteria which produce IAA have been found to

promote root growth by as much as 50% (Patten). Increased root growth leads to healthier plants, less erosion and other benefits.

Bacteria from the Kolli Hills were tested for production of IAA as a way of indicating their ability to promote plant growth. Of the 24 bacteria screened, 11 formed cultures in the media.

Out of those 11 bacteria, one tested strongly positive for IAA production, two others tested positive, and five more tested weakly positive. Only three bacteria tested negative.

That so many bacteria can promote plant growth is reason for optimism. The soil has built in buffers to help plants adapt, and we need to do all we can to protect it.

Plants Genetic Diversity Experiment – Finger Millet

Genetic diversity is what allows plants to adapt to changing weather, pests and other pressures. The more genetic diversity within a plant species, the easier it will be for that species to adapt.

I conducted a pilot project to study the genetic diversity within finger millet in the Kolli Hills to indicate how resilient millet might be. The project only analyzed the current state of diversity and did not study whether diversity was increasing or decreasing.

Seeds of eight different land races of finger millet were collected from the Kolli Hills and tested for genetic diversity using Random Amplified Polymorphic DNA Analysis (RAPD) through a Polymerase Chain Reaction (PCR). Nine of the ten primers used for testing produced useable banding patterns.

The results from the pilot study show promise for a high level of genetic diversity. This indicates that the millets in the Kolli Hills probably have the genetic resources to be resilient to changing climate and pest pressures. Plants and soil are much more prepared than people.

This was my first experience with molecular biology and I improved with practice. However, some of my first experiments were not of high enough quality. I would try to test more samples than I could handle at one time and the results showed it. However, I learned to work with a small number of samples making sure to follow the procedure meticulously. Fewer experiments were done this way, but better results were obtained.

It would be useful to compare the results from the larger study to those from previous years. Many farmers have been saying that there is a decrease in diversity due to the loss of millet types. The comparison of studies would provide verification of this concerning trend.

Challenges Millet Farmers Face Concerning Weather Volatility

The effect of predicted changes will have on crops is uncertain, but will probably not be beneficial. For example, millet, the plant I studied most, is temperature and drought tolerant, but grows best in a temperature range from 26-30 °C (ICRISAT). The predicted temperatures are approaching the upper limit of that range. Many interrelated factors influence how farmers in the Kolli Hills adapt to weather volatility. The major challenges are:

Uncertainty. There are many unknowns about weather and how it might, or might not, change including: when extreme events will occur, how sensitive millet will be to changes in weather and what the most resilient farming system will be. All anyone can do is make an educated guess.

Significant Consequences for Mistakes. Farmers in the U.S. have buffers to smooth out rough times such as irrigation for drought, chemicals to kill pests, and crop insurance for total crop failure. Farmers in the Kolli Hills don't have such buffers which increases the consequences for mistakes. Nevertheless, some farmers think that climate change is just a short term problem that they can "suffer through."

Understanding the Advantages and Disadvantages of Tradition. There are advantages to effective traditional farming practices in times of consistent weather, but if weather conditions change, practices need to change. In this scenario, following tradition becomes a disadvantage. Religious practices could hurt, or help, the transition. For example, farmers in the Kolli Hills are required to wait for the religious headman to plow his field and plant before they can start doing the same in their own field. This could help, or hurt, depending on the degree to which the religious headman adapts to changing weather.

Few resources to help adapt. Assuming a millet farmer in the Kolli Hills wants to adapt and change the crops they plant, improve seed selection and install a water retention system. The MSSRF provides information and guidance. However, other than the farmer's resources, there are few resources to help them adapt especially when compared to the United States land-grant universities, experimental farms and USDA researchers.

Markets Do Not Favor Millet. With the new roads put down by the government, Kolli Hills farmers are beginning to participate more in the major markets surrounding the Kolli Hills which are for rice and cassava. This is causing farmers to abandon millet in favor of cash crops that are more profitable. However, in the long term, especially considering weather volatility, millet could be more profitable.

Switching Crops. Switching back to millet won't be easy because seeds for millet and other crops can only be stored for a few years before they won't germinate. This essentially means that if a farmer doesn't continually cultivate locally adapted millet varieties, those varieties could be lost and can't be used in the future to adapt to weather volatility.

Soil Quality. Farmers in the Kolli Hills plow their soils and leave them bare for extended periods. This makes the soil vulnerable to erosion, especially as extreme rains increase because of the steep slope of the Kolli Hills. The extra water will likely run off and not be retained in the soil for crops.

Gender Inequality. Women in India are given lower status than males. One of my friends at the foundation in Chennai said that her parents put arranging her marriage and picking the right decorations for the wedding above finishing her Ph.D. We need everyone thinking and doing what they can. Stifling the potential of half of the population does not help.

Multiple challenges at the same time. Dealing with one new challenge is hard enough, but increased weather volatility could result in multiple problems for farmers including increased temperatures, more extreme rainfall, different insects and changing weed species. As well, farmers are having to deal with increased commercialization and that their children want to pursue careers in cities rather than farm in rural areas.

Ways to Help Millet Farmers of the Kolli Hills Help Themselves

Because people working together to help themselves leads to lasting improvements, a priority for the MSSRF is to help farmers develop community self-help groups so they are more self-reliant and less dependent upon outside help which can come and go. Farmers have established self-help groups to share machinery, evaluate practices, as well as build markets for millet and millet products.

Outside aid should be given with the aim to help farmers become self-sufficient. Outside groups postponing natural consequences in an unsustainable way can lead to increased suffering in the long term because sometimes action won't be taken until suffering has occurred. An external expert in agriculture can best help farmers by living in their community and working directly in the field with them, like Norman Borlaug did for long periods of time in Africa.

The role of government in agriculture should be to carry out large-scale projects such as building roads, regulate domestic markets, promote exports, negotiate treaties, conduct research to secure future production, protect the environment; implement foreign policy to promote food security on a global scale.

Non-profit organizations like the MSSRF and Gates Foundation are effective at improving technologies for small-holder farmers, spreading innovations, and encouraging the implementation of best practices from around the globe.

Business play a vital role. As Bill Gates said in his 2009 speech at the World Food Prize, “Research companies can take the technologies they’ve developed for big agriculture and apply them to the needs of small farmers. They shouldn’t try to change the customer to suit what they sell; they should change what they sell to suit the customer – many different crops, fertilizer that suits different soils, seeds sold in packages of 1 kilogram, not 50. In the poorest countries, some of these products need to be royalty free, or many customers won’t be able to buy them.”

What Millet Farmers Say They Need

In my interviews, I asked the Kolli Hills millet farmers what they think would most help them. In order of most commonly mentioned, they said:

Machines to Grind Millet. The MSSRF has introduced machines in some villages that will grind some varieties of millet into flour but not all varieties. The machines save long hours of pounding millet by hand. Compared to hand grinding, the machines yield less flour per pound of grain put in, but farmers still prefer the machines because it frees them to do other things. Hand pounding can also lead to repetitive stress injuries.

Loans. Loans are desired by millet farmers for many reasons. In the past, loans have only been available if the farmer grows cash crops like cassava that the creditor can seize in case of default. The farmers would like to have loans for millet production. But it is uncertain whether providing loans would actually benefit millet farmers. Buying consumer goods, or even fertilizer or putting in a well for irrigation, could lead to a vicious cycle of indebtedness. Some farmers said they would like to be given fertilizer and irrigation wells. Even if these gifts could be continued forever, it is uncertain whether this is the best way to increase yields for the long term.

Other Ways to Help Millet Farmers Help Themselves

If the same talent, effort and resources were put to improving small-holder agriculture as has been put into big-holder agriculture over the past decades, there would be ample resources to help small-holder farmers and the advances would be significant.

First Understand and Improve Existing Practices. Traditional farming practices have been stereotyped as ineffective, and many are. Nevertheless, it is important to use science to determine if, and why, traditional farming practices are effective or not because:

* We don’t know what we don’t know. In the zeal to increase productivity, we could be plowing over unrecognized plants, ecosystems, practices and more that could be of importance now and in the future. For example, even though rice is tastier than millet and therefore brings a higher price at market, millet and other such underutilized crops are still important. If there is a significant change in precipitation or temperature, it is possible that millet, sorghum or other underutilized plants could be what we need to grow and consume no matter if we like the taste less than rice. The continuous growing of underutilized crops is important because, if not, varieties and the knowledge to grow them could be lost.

* We can mitigate disadvantages of traditional and new practices. For example, if a farmer replaces his cows with a tractor, there could be gains in efficiency, but there are also no more cows in the field to provide manure. If this tradeoff is understood, the farmer can mitigate the consequence by composting.

* Do no harm. At the least, a new farming practice should do no harm in the short term but especially in the long term. A new practice should not be promoted with the hope that a better practice will come along when needed. In many situations, it is better for farmers to stick with traditional practices.

When evaluating traditional practices, it is important to:

Look at the Long-term. New practices can show promise for a few years and be heavily promoted as superior to traditional practices. Over the long term however, many new practices taper off or even harm. In the long term, traditional practices can result in higher yields than unproven new practices.

Test new practices in the field. Ideas for improving yield that work in a lab or under controlled conditions might yield less when compared to traditional practices in the field in a certain location because of factors that researchers did not consider.

Consider the total cost to the farmer. To be recommended, a new practice needs to be significantly better than an existing practice to offset the cost, time and effort to implement a new practice.

Therefore, in most situations, existing practices should be improved before introducing new because many farmers have resistance to new practices. For example, because farmers in the Kolli Hills already plant millet, try to improve millet seed varieties, as the MSSRF is doing, before introducing new crops. Once existing practices have been improved as much as possible or farmers are open to change, implementing best practices from around the globe can lead to continued improvement.

Introduce Best Practices. Once existing practices are understood and improved, introduce best practices which have proven themselves in comparable environments. For example, the millet farmers I interviewed rarely use water catching techniques even though such systems have been shown to work in Africa. When best practices are introduced, it is important that farmers understand how to implement them and to not over use them as has been done with fertilizer and irrigation. If some is good, more is not always better.

Use Demonstration Plots. Many people think that demonstration plots are just to help farmers. There is more to it. Demonstration plots get agricultural scientists in the field and force them to prove what they are saying. Many educated people don't like being tested in the field. They want to be tested on paper – multiple choice and short answer – but agriculture is not that way because farmers believe and act on what they see. In one village, Valkuliputi, only millet has been grown for decades. This year, two farmers decided to each plant a field in cassava because of the crop's success in other villages. The inhabitants of Valkuliputi told me that they will watch those two fields. If the cassava does well, they will convert to cassava production, and if not, they will stay with millet. Demonstration plots that show the effectiveness of resilient practices will lead to farmers adopting the techniques more readily because scientists get in the field and prove what they are saying.

Make Improved Seed Affordable. In the Kolli Hills, like many other places, farmers save seed to plant the next year. Farmers avoid buying new high yielding varieties from the MSSRF because of cost and the feeling that their traditional seeds have been good enough for many years. If improved seeds were more affordable, more farmers would be willing to try them.

Increase Demand for Millet. If farmers do not have an incentive to grow, they won't. The MSSRF is helping millet farmers create demand for millet in the cities through organic shops. Food aid can also be used as a tool to support local crops as Roger Thurow and Scott Kilman write about in their book "Enough." Purchasing food aid locally and giving it to those in need can simulate a functioning market and help regions move toward self sustainability. Thanks in large part to Dr. Swaminathan, government food aid in the Kolli Hills includes millets bought locally.

Improve post-Harvest Storage. Weather volatility threatens to lower the yields of farmers everywhere, but the effect of yield losses can be offset by reducing waste. According to the UN Environment Programme, a third of all food produced each year is wasted. A farmer in the Kolli Hills, Nelamani, told me that she bought high yielding seed varieties from the MSSRF and saw an increase in yield. However, the gains were lost because the harvest was stored under a tarp outside and a rain caused the grains to sprout and spoil. By improving post-harvest storage, the food supply can become more abundant without further taxing the earth.

Improve Soil Quality. Soil is the base of productivity for a farm and acts as a buffer for farming ecosystems. Action needs to be taken to protect soil now, because erosion and other problems will get worse if rains become more intense. There are many options for protecting soil quality. Growing fodder grass around terraces can stem erosion and provide another source of productivity. Green manures and composting are other options. Some farmers already use these techniques but they are not universally accepted.

Take Action In All Areas. It will take everybody thinking and working to prepare for weather volatility. Gains need to be made wherever possible because we don't know where success will come from. There is no silver bullet.

Impact of Research Project

Concerning the impact my eight-week project, I hope the farmers in the Kolli Hills learned something from talking with me because I learned a tremendous amount visiting with them.

The biggest impact of this project has been on me and my future work, not the farmers in the Kolli Hills. By doing the project myself and getting help from several research teams, I learned a lot about a range of things.

For my project to have impact, the next step would be to present this report to experts, get their feedback, restructure everything, talk with more experts, restructure everything again, realize I need to quit trying to do it all myself then join a research team at the MSSRF. However, that is not feasible because I am going to go to Purdue University in Indiana (not India). Maybe someday I will accomplish something that helps people globally.

Nevertheless, the cumulative impact of many people around the world getting started, experimenting, and making improvements big and small, is what will lead to progress.

Lessons I Learned / Re-learned

I will continue to learn, but the internship experience helped me better understand, clarify and consolidate my thoughts about a range of topics.

Learn from people and history. This seems obvious, but as Dr. Borlaug said, "Man seems to insist on ignoring the lessons available from history." Dr. Swaminathan is an example of someone who learns from the past, and it shows in the approach of the MSSRF. I learned a lot from his book, "From Green to Evergreen Revolution" that evaluates the Green Revolution and what can be done to improve.

Henry A. Wallace significantly influenced me when I first started learning about agriculture. I went to Henry A. Wallace elementary, my family lives on land Henry Wallace once owned and my first “big” report I wrote in elementary school was about him. As many say, he was a visionary who worked for the common man and that is something I will always respect.

Importance of will and effort. "The word 'impossible' exists mainly in our minds but given the requisite will and effort, great tasks can be accomplished" is advice Dr. Swaminathan's father gave him that we should all remember. Bill Gates, Howard Buffett and others have said that we know enough about what needs to be done in agriculture, we just need to muster the will to do it.

In agriculture, the primary motivation should be to serve humanity. In his Nobel acceptance speech, Dr. Borlaug talked about the importance of educating “scientists and scientific leaders whose primary motivation is to serve humanity.”

Err on the side of people. Dr. Ejeta G, World Food Prize Laureate in 2009, spoke in his acceptance speech about his decision to “err on the side of people.” Like Ejeta Gebisa, Norman Borlaug, M.S. Swaminathan and many others, I am going to strive to “err on the side of people” and see how much good I can do.

Asking questions and independence. Why? What if? What are the actual versus claimed advantages and disadvantages? Who really gains and loses? What will be lost? What about the long term? What is the backup plan? What is it that we don't know that we don't know? What if we are all wrong? Critical thinking and questioning rather than just going along can advance the common good in the long term.

Understand Trade Offs. Fertilization, irrigation, and other intensive cultivation techniques could be used to overcome short term weather volatility, but they can sacrifice future production potential if abused. We need to increase the timeframe for evaluating practices and go with what will result in the most production over many decades and not just a few years.

Advantages and Disadvantages of the Green Revolution. As Dr. Borlaug said in his Nobel Peace Prize Acceptance Speech, “There are no miracles in agricultural production. Nor is there such a thing as a miracle variety of wheat, rice, or maize which can serve as an elixir to cure all ills of a stagnant, traditional agriculture.” Being an intern in India helped me better understand the Green Revolution. It seems like different interests present the history of the Green Revolution – who did what and the impact of it – in different ways depending on what profits them. Ignoring different interpretations might be convenient in maintaining relations, but there needs to be clarity so better learning can occur and mistakes can be avoided.

The Green Revolution's advantages were many and saved a billion lives. The disadvantages of the Green Revolution were in large part due to how Dr. Borlaug's contributions were misapplied for short term gain. As proven in his life, Dr. Borlaug was motivated by helping people, not money, and he more than did his part to contribute to the common good.

Dr. Borlaug knew the Green Revolution had disadvantages and that the term was being distorted. In his Nobel Peace Prize acceptance speech in 1970 he said, “Perhaps the term ‘green revolution’, as commonly used, is premature, too optimistic, or too broad in scope. Too often it seems to convey the impression of a general revolution in yields per hectare and in total production of all crops throughout vast areas comprising many countries. Sometimes it also implies that all farmers are uniformly benefited by the breakthrough in production. These implications both oversimplify and distort the facts.”

Dr. Swaminathan was one of the main facilitators of the Green Revolution in India, but in his book, “From Green to Evergreen Revolution,” he talks about how partisan interests distorted the Green Revolution which led to land degradation and harmed rural communities. By re-evaluating, he has been able to help his foundation and India change paths and move even closer to the principles to which they strive.

As Bill Gates said in his speech at the World Food Prize in 2009, the challenge for us is that “the next Green Revolution has to be greener than the first. It must be guided by small-holder farmers, adapted to local circumstances, and sustainable for the economy and the environment.” Gates also said, “The last thing anyone should do is create short-term gains for poor farmers that have long-term costs for their children.” I think Dr. Borlaug would fully agree and would be working with vigor to make things better.

Just focusing on feeding 9.5 billion people by 2050 ignores the “Population Monster.” As Dr. Borlaug said, “the frightening power of human reproduction must also be curbed; otherwise the success of the green revolution will be ephemeral only. Most people still fail to comprehend the magnitude and menace of the ‘Population Monster.’”

Need for more workers. Reading through the biographies of speakers at the World Food Prize Symposium it seems like we have enough knowledge and technology to make significant progress. But we need more workers doing the unglamorous work of “taking it to the farmer” in the field.

Profit and Non-Profit. Can the goals of feeding the World and meeting Wall Street’s profit expectations both be accomplished at the same time? Progress can be made while working under the profit motive, but will the profit motive cause us to stop short when doing the right thing no longer profits us? That does not mean helping others and personal gain are mutually exclusive. Bill Gates is an example of someone who has had significant personal success and has gone beyond profit to help others. In his 2012 annual letter, he said “The private market does a great job of innovating in many areas, particularly for people who have money.” The private sector has made many advances that can only be bought by farmers with money or access to credit. What if the people in the private sector who make it so innovative focused themselves on small-holder farmers?

When I look at a situation and think freely about how to make things better, I have many ideas. After I evaluate the ideas in terms of feasibility, Dr. Swaminathan’s approach, impact on people, and values that are important to me, there are fewer ideas but still some. If I then evaluate the remaining ideas from the point of view of business profit, I feel ... ugh. I feel like I should not let profit get in the way of doing good things. Then I feel inspired again. There is so much good that can be done if we don’t think about our own profit.

If I ever have a truly win-win business idea that inspires me, I will develop it but I am leaning to working for a non-profit foundation, university, or organization like Dr. Swaminathan, Dr. Borlaug and others. I want to “err on the side of people” and focus on developing non-profit ideas and see where this leads. I want to make a reasonable living but the true profit from a non-profit is working for the common good.

Importance of Incentive. There is a balance between helping others and doing things for them. In India, there is a strong social ethic and desire to help the poor as exemplified by the Public Distribution System for food and a Rural Employment Guarantee. However, both of these programs need to be carefully managed because they can take away people’s motivation to work for themselves or others. While I was in India, on several occasions I saw the Rural Employment work crews sitting on the side of the road instead of working. I was told this was common and that the workers are still paid. This creates a challenge for small-holder farmers that employ laborers because people won’t work for farmers with standards for efficiency unless they are paid much more than the government programs give them.

Vote with your purchases. Decisions we make as consumers affect the entire food network. We choose with our purchases what type of agriculture system we support. Buying a wider range of grains promotes a diverse farming system that is more resilient to weather volatility.

Growing is location specific and a range of agricultural systems are needed. In the same field, you can take one step and numerous factors can change – soil type, slope, amount of sun and more. As Dr. Swaminathan says, appropriate ecotechnology is needed to make the most progress. Innovation needs to be able to adjust to local conditions to have the greatest impact.

Have proper respect for nature. Agriculture is by definition trying to modify nature and produce more useful plants than would normally grow. However, this doesn't mean that nature will stay put and do as told. Nature pushes back as evidenced by pesticide resistance, desertification and more. Instead of always fighting nature, in some situations, we should respect it and enhance the aspects of nature that can increase crop production like crop rotation, composting, cover cropping and more.

Minimalism. When people invited me into their homes in India, I realized how simply and well they live, especially compared to the amount of stuff Americans have. The graduate students at the MSSRF lived in one small room that is about the size of a bedroom in an American home. They sleep on bamboo mats on the concrete floor and roll the mats up during the day to have a living space. This lifestyle has many advantages because the fewer things consumed and used, the lower the burden on natural resources. Living with less in India really made me re-evaluate the importance of what I have. At my home in Iowa, I tried sleeping on the floor for some weeks, but one night I woke up in my bed and took it as a sign that that is where I should sleep. However, I have started eating more like an Indian, consuming less meat and more vegetables.

Valuing the USA. Living in another country helped me appreciate the United States. I didn't value safe tap water, traffic rules, and clean cities until I had to live without them.

Personal Path. After going to India, I see myself working to improving agricultural systems from the ground up, not just focusing on only one aspect. It takes looking at the entire farming system to make lasting improvements. I am leaning toward working for a non-profit foundation, university or government organization like Dr. Swaminathan, Dr. Borlaug and others. These approaches have fewer intrinsic special interests and will allow me to make independent assessments of agriculture.

Suggestions for Future Interns

After completing my internship, I thought about what I learned and how I could do better in the future at different research stations. The following are my top nine suggestions:

Don't wait to be selected. Select yourself. If you are not selected, apply again, apply to other programs or select yourself. Find a way to create your own internship nearby or far away. You are needed. In Dr. Borlaug's Nobel Peace Prize speech in 1970, he said, "to convert these potential values into actual values requires scientific and organizational leadership. Where are those leaders? Where are the leaders who have the necessary scientific competence, the vision, the common sense, the social consciousness, the qualities of leadership, and the persistent determination to convert the potential benefactions into real benefactions for mankind in general and for the hungry in particular? There are not enough of them now; therefore we must try to identify and develop them in our educational systems and we must utilize them in our campaigns for food production. We need them and need them badly, for it is tragic to let potential values languish for want of leadership in capitalizing the potential. This is not theory; this is reality, as illustrated by the fact that the leadership has been the determining factor in the relative success of parallel but different crop production programs within the same country."

Prepare before going. Talk to people and get experience locally to prepare. Read about where you are placed. A good source is the World Food Prize website which also includes former interns reports. Think about what you might want to do then prepare yourself for several options.

When you first arrive, get oriented, explore, then make decisions. Exploring will help you find the right project, ways to contribute, and help you be more effective the rest of the time. Talk to people about their work. Some research projects may not be listed online or have changed dramatically.

Find a mentor. You are new and it is important to find someone who can give good advice. Pick someone who is knowledgeable but also has time for you and wants to help you learn. Since internships are short, it is probably more important to pick a mentor with a good project you can learn from rather than the project you are most interested in.

Choose your project well. The options range from developing your own project to joining an existing research team already working on an established project. If you are going to develop your own project, start quickly and have clear goals because the eight weeks pass fast. It is important to know how your data fits with the work others have done in order to build upon it. You will have a lot of work but will learn a lot. If you are going to join an existing team, consider first finding a good mentor then join their project. Research centers have established specific projects because they believe those projects have the most potential for impact. What ever you do, get to work because effort will lead to more learning and better results than just skimming over multiple projects.

Enjoy people and what is unique. One of the most unique things about where you are going will be farmers in the field. Get in the field and work with farmers to learn about their thoughts, questions and approaches to agriculture. Don't go thousands of miles away to do something you can do near home.

Learn by Wandering Around. During four days when there was no translator, I took hikes through the fields and forest. In addition to seeing farmers planting millet, cassava and other crops, I saw boys using sling shots to hunt birds, watched cow behavior in rice fields, and spotted new plants and insects I had never seen before and still don't know what they are. Cassava is a 12 month crop and I saw it both harvested and planted on the same day in different fields. After one hike, I found a leech that had latched onto my right leg right above my sock. I saw two funerals while in the Kolli Hills. The whole village would gather and have a parade and shoot cannons to mourn. The occasion was sad but the sense of community was heartening. In the major town of the Kollie Hills, I talked with students walking to school, played volleyball with a mix of boys and middle-aged men, and spent time at the village resource center run by the MSSRF.

Share Whenever You Can. During one interview, a farmer kept mentioning a special fruit tree that he had but he didn't know what the fruit was used for because it wasn't native. After talking, we went to look at the tree and he broke open one of the fruits to show the big seed inside. I instantly recognized it as an avocado and felt really good because I was able to share with him what it was and ways to eat it. I wanted to make something with him but the avocados were still green.

Another time, a farmer invited me into his home to see his coin collection which was kept safe in tin boxes and wrapped in cotton cloth. I was able to contribute because I had a new type of coin from the city that had not spread to the rural areas yet. In exchange, he gave me coins and bills that had wheat, tractors and other agriculture related symbols.

Help Anyway Possible. At the Research Foundation, I had the opportunity to help move and level dirt to build a badminton court, cook, pick up trash, harvest sugarcane, and share stories about the U.S. I also got to know farmers better by helping them plow, weed, plant, and dry their harvest and by swimming in a water fall with them.

Understand the human side. Before traveling to India, I imagined people who cut primary forests as villains. They were people who cleared whole mountains in a single day for profit, leaving nothing but waste and destruction behind. The reality in the Kolli Hills is much different. The forest is cleared one small parcel at a time by people who want to provide for their families. They use the land until the soil is exhausted then clear a new bit so their family doesn't go hungry. The process is gradual and has a very human element. Telling people that they can't cut anymore trees won't work because they still need to provide for their families. Efforts to stop deforestation will have to be paired with soil preservation and finding other livelihoods so the people can still live. As Howard Buffet has said, "No one will go hungry to save a tree."

If asked for feedback, know there are advantages and disadvantage to everything. Shortly before I left the MSSRF, Dr. Swaminathan invited me to meet with him and his administrators for tea. He asked me what recommendations I had for the intern program. The first thing I thought of was more structure for intern research projects but before I said that, I realized it was me who actually sought so much freedom in my work from the first day. The freedom increased the challenge of the project and amount of the work but I learned more and it was well worth it. In other words, accept the disadvantages of something that is overall advantageous. You can't have your chutney and eat it too.

Try new things. One of the most rewarding aspects of going to a different culture is trying different ways of doing things. The barriers of language and tradition only get in the way if you let them. By watching people and eventually joining in, I learned to cook Indian food, play cricket, climb coconut trees and many other things. People loved that I was willing to try their way of living, and I had a great time doing it.

Appreciation

In addition to my family, I am very appreciative of many people who have helped me.

World Food Prize

This experience would never have been possible without **Norman Borlaug, John Ruan Jr. and John Ruan the III, Ambassador Kenneth Quinn, Lisa Fleming, Jan Douglas, Catherine Swoboda, Keegan Kautzky** and all of the others who work so hard to make the World Food Prize possible. I have learned more than I know at the Symposium over the years.

I have wanted to be a Borlaug-Ruan Intern since I first heard Amb. Quinn speak about it at the 2008 World Food Prize Symposium when I was twelve. After the interviews to be a Borlaug-Ruan Intern for 2013, I withdrew myself because, at the time, I wanted to spend a full year in China and not return for the World Food Prize Symposium in October. Three days before the Intern Orientation in May, I was told that there was an opening for the internship at the MSSRF because the student who was placed there had a health issue. I accepted the placement because of the renoun of Dr. Swaminathan but I had a very short time to prepare before leaving for India. I am very thankful the World Food Prize made this opportunity possible. Because of my wonderful experience in India at Dr. Swaminathan's Research Center, I have decided to spend the second part of my Bridge Year at CIMMYT, the agriculture research station in Mexico where Dr. Borlaug did much of his research and his influence continues. I hope to go to China in the future.

The **Kolli Hills Farmers** were very generous and I learned a lot from them. It seemed like at every interview they would offer me food, mangos from the tree we were sitting under, a jackfruit they had just picked or even a full meal if it was anywhere close to dinner time. I especially appreciate **Ganesan** who let me help plow, weed and plant millet in his field using the traditional practices of the Kolli Hills.

MSSRF

Many people at the MSSRF helped me develop my research project and I am very thankful for their help.

Dr. Swaminathan's foundation made it possible for me to come to India. I learned a lot from the conversations he had with me. His generosity was incredible. At several occasions during the internship, I wore the traditional clothing of Tamil Nadu such as when the President of India visited. On my last day, Dr. Swaminathan presented me with a set of traditional clothes as a gift.

Dr. Rajalakshmi and **Dr. King** provided guidance for my project. They gave me freedom and helped me connect with others who could help me.

Dr. Nambi has many years of experience as a climate change scientist and his advice was very helpful. He helped me define my focus for interviewing farmers and refine my survey questions.

Dr. Ganesh Govindan and **Mrs. Sowjanya** taught me the lab techniques of analyzing the diversity of millet plants. This was my first experience in a molecular biology lab and I still have a lot to learn, but something Ganesh said will stick with me "Go slow at first. Do things the right way and get good results. Speed will come with practice."

Kathir, Jagan, Purushoth and **Baskaran** taught the techniques of studying soil bacteria.

The **Kolli Hills Farmers** who talked with me were very patient and gracious with their time. **Ashokma** and **Prakesh** translated my interviews of the Kolli Hills farmers. Without them I would not have been able to learn much.

Ashok, Shanka, Suji, Karthik and many others helped me adapt to India and made my stay enjoyable. Thanks for teaching me to play cricket, taking me to your home to cook Indian food and helping me explore India.

Purdue University

I first met **Dr. Gebisa Ejeta** in 2008 when I was 12, the year before he was the World Food Prize Laureate. He was the one who first told me about the exciting things happening at Purdue. In 2012, I got to meet **Dr. Akridge**, Dean of the College of Agriculture, who attended the World Food Prize Symposium. I visited Purdue a few weeks later and got to talk with **Dr. Chapple**, Head of the Biochemistry Department; **Dr. Anderson**, Head of the Agronomy Department; and **Dr. Tuinstra**, Agronomy Professor. Afterwards, I knew it was the right place for me.

My academic advisors, Mrs. **Pogranichniy**, **Mr. Taylor** and **Dr Okos**, have given great guidance on my degree plan to study biological engineering, biochemistry and agronomy.

Dr. Steven Beering, President of Purdue University from 1983 to 2000, has had a major impact on my life because of the Beering Scholar program at Purdue. Being named a Beering Scholar has inspired me and facilitated my pursuit and application of knowledge.

Iowa State University

I will always be grateful to the wonderful people at Iowa State University because I have benefited greatly from the programs, lectures and workshops on campus. I have learned so much just wandering around campus and talking with professors whose doors were open. **Dr. Burras**, professor of soil science, was the first to spur my scientific interest in soil. **Dr. Rao**, Head of the Biochemistry Department and **Desiree Gunning** have always been very helpful.

USDA

During the period when I was thinking about what I could do during my internship, I heard though the news about the USDA Report on Climate Change that had just been published in February 2013. It caught my attention because it is the most complete report to date in the World on Climate Change. A lead author was **Dr. Jerry Hatfield** at the USDA Agricultural Research Service at Iowa State University. I had the opportunity to visit with him which helped me a lot.

During the summer of 2012, I was part of the USDA's Ag Discovery Program at the University of Maryland with **Dr. Ken Ingram**. During the three week program, we spent time learning at the USDA's Beltsville Agricultural Research Center (which is the largest agricultural research facility in the World), National Plant Quarantine Center, Animal and Plant Health Inspection Services, the Port of Baltimore's import inspection facilities, National Agricultural Library and other USDA labs. This experience helped me see a side of agriculture that I had not been exposed to.

High School Teachers

I learned a lot in high school and am especially appreciative of **Mr. Hepburn** for teaching me the basics of lab work and **Mrs. Burns** for being my sponsor for the 2010 Global Youth Institute.

Practical Farmers of Iowa

I am a member of PFI which is a group of "independent farmers whose mission is to advance profitable, ecologically sound, and community-enhancing approaches to agriculture through farmer-led investigation and information sharing." I have learned a great amount from the farm visits because there are a lot of interesting people doing interesting things.

Pioneer DuPont

I live a few blocks from Pioneer DuPont's headquarters in Johnston, Iowa so I know people who work there. Security is tight but I go to Pioneer and events there when I can get in. Thanks.

Bill Gates, Howard Buffet and Jeffery Sachs

Thank you for coming to speak at the World Food Prize in Des Moines in 2009 and for your publications.

Citations

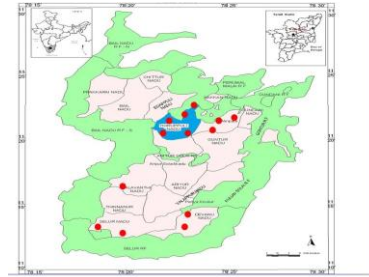
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4th of July with Dr. Swaminathan.



Interviewing a farmer.



Map of Kolli Hills and Villages visited.



Dinner with a farmer.



Avocado I taught farmer how to use.



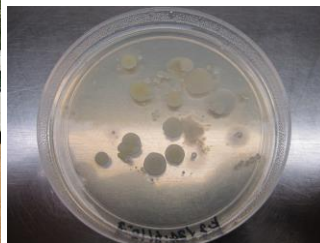
Looking at an intercropped field.



Helping farmers plow and plant millet.



Fun with Friends.



Bacteria of the Kolli Hills.



Bacteria suppressing a fungus.