The Potential of Agroforestry to Reduce Energy Poverty and Environmental Degradation in Rural Zambia

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Abstract
Over the past decade, increased charcoal production in rural areas of southern Zambia has resulted in large-scale deforestation, which has contributed to a variety of environmental problems such as erosion, temperature volatility, and increased wind speeds. The increase in charcoal production is driven by several factors including urbanization, a nationwide energy deficit, and rural poverty. Previous studies have demonstrated the relationship between urban charcoal demand and increased levels of deforestation in other Sub-Saharan African nations. This paper extends these studies by examining how this dynamic impacts not only the environment, but also the livelihoods of rural farmers in southern Zambia. Environmental degradation leads to less productive farms, which in turn leads more farmers to begin producing charcoal to supplement their incomes. This is a vicious and self-perpetuating cycle that not only destroys the landscape but also exacerbates poverty. Based on interviews and field observations, this paper analyzes how agroforestry, as an entrepreneurial alternative to current agricultural practices, can be used to halt and even reverse some of the drivers of the vicious cycle. Agroforestry can also be used to mitigate some of the environmental problems associated with deforestation as well as help prevent increased rural charcoal production. Based on these findings, this paper recommends steps be taken to regulate charcoal production and promote entrepreneurial and sustainable agricultural practices that can diversify farmers' outputs and increase incomes.

I. Background

Biomass remains the dominant source of energy in Sub-Saharan Africa and therefore has been the subject of many studies beginning in the mid 1970s. Most of these were focused on estimating the longevity of forest resources in light of the growing dependence on biomass. While some research suggested that agricultural growth was primarily responsible for deforestation (Foley, 1985), most studies determined that the primary driver for deforestation was the demand for fuel wood and that this demand could lead to a severe crisis in the future if not managed properly (Kamweti, 1984). Later studies began to make the distinction between urban and rural fuel wood consumption, finding that most rural areas rely on firewood rather than charcoal, which is most prominent in urban centers. This is because urban populations do not have direct access to firewood due to their isolation from forests. Charcoal is also a more condensed form of energy (in terms of kJ/g) than firewood and is easier to transport and store in urban centers. Therefore, although charcoal is produced in rural areas, it is primarily consumed in urban centers. Furthermore, these studies found that firewood does not pose as severe of a threat to forest resources as charcoal does (Johnsen, 1999). Firewood has served as the main energy source for centuries in rural Africa and is obtained by collecting it from

the ground or cutting single branches rather than by chopping down entire trees. In contrast, charcoal production begins with the harvest of entire trees. It has only been in recent decades, with unprecedented levels of urbanization and the ensuing increase in charcoal demand, that deforestation has been such a large issue.

Although the relational dynamics between urbanization, increased charcoal production, and deforestation were identified in these studies, the proposed solutions generally centered on increasing the efficiency of producing charcoal so that forest resources would last longer. Many government initiatives focused on designing and distributing more efficient stoves that would require less charcoal. Others focused on improving the efficiency of the charcoal production process. It is estimated that inefficient charcoal production techniques result in charcoal requiring about 5 times more wood than would otherwise be required when cooking with firewood (Kammen and Lew, 2005). As a result, the Zambian government created a guide for producing charcoal to try and improve the efficiency of the process (Hibajane and Kalumiana, 2003). Unfortunately, many of these projects and government initiatives fell through due to lack of resources and monitoring schemes and have not resulted in the intended reduction in charcoal demand.

Finally, the significance of climate change and how it relates to charcoal production and deforestation cannot be overstated. Climate models for Zambia predict that the country has seen more droughts and major increases in heavy rainfall events. While droughts pose a direct threat to farmer livelihoods, increased heavy rainfall events are dangerous in terms of erosion. This is especially true when the landscape has been cleared of trees that can help to stabilize soils in the case of heavy rain events. Furthermore, models indicate that Zambia will experience shifting seasonality, which can disrupt farmer production, and an increased incidence of extreme weather events such as frosts (IPCC, 2007). When these issues are taken into consideration in the context of Southern Zambia, it is clear that deforestation not only poses a threat to forest and energy resources, but can also exacerbate some of the predicted climate changes that the country will experience.

This paper seeks to address the rural side of the energy, climate, poverty nexus by describing the ramifications of increased charcoal production on rural farmer livelihoods. I report here my experience working in rural Zambia during the summer of 2013 from June to August in the area around Chikuni, in Zambia's Southern Province (Figure 1). The research for this project grew organically out of the experiences I had during the Global Social Benefit Fellowship sponsored by Santa Clara University's Center for Science, Technology, and Society. My original assignment was to travel to the Chikuni Jesuit Mission in Southern Zambia and work to help develop an agroforestry guide under the direction of a local expert.

One of the Chikuni Mission's main programs is the Taonga (meaning welcome in the local language) program, which is a distance education initiative to help reach isolated rural children. Children living in rural areas often live several kilometers from the nearest government school, meaning getting to and from school is a time and energy consuming activity. Furthermore, most schools in Zambia charge fees for uniforms and school supplies that poor families cannot afford (Burger, 2011; Kaluba, 1986). Several years ago, Chikuni began the Taonga program to reconcile these difficulties. The mission runs a local radio station that serves the local region, giving Chikuni a unique opportunity

to reach even the remotest villages. The program involves the use of solar powered radios that enable children to gather together, under the direction

Figure 1. A map of Zambia highlighting Chikuni, the primary location for the project. (CIA World Factbook)

of a mentor, and listen to educational material broadcast from Chikuni. This material consists of half-hour long lessons based on interactive radio instruction (IRI). IRI is an innovative alternative to formal schooling and has proven to be effective (Potter & Naidoo, 2009). The programming was originally written and recorded by the Zambian Ministry of Education and was used nationwide until the government cut the funding for the program. Because the mission owns their own radio station, they were able to continue broadcasting these educational programs.

Currently the mission serves 21 rural schools, each of which have a solar powered radio to which the children and mentors listen. Some of these radio classes are held indoors in formal classroom buildings (Exhibit 1) while others are simply held under the shade of a tree (Exhibit 2). While the IRI model is central to the Taonga program, it is only half of Chikuni's educational outreach. Along with the radio programs that teach things such as math, literacy, and health, there is an agroforestry component as well. Chikuni has focused extensively on improving farmer livelihoods due to the fact that the majority of the people it serves rely on subsistence agriculture. Recognizing the importance of teaching the next generation of farmers the value of sustainable farming, the Taonga program has set up agroforestry "gardens" at each of their IRI schools. Because the rural schools are often located in the center of the remote villages, they serve as meeting locations for the community and children to observe and experience sustainable farming practices.

It was these gardens, and the programs being implemented that served as the basis for my research. Although the gardens have been initiated at nearly all of the IRI schools,

the program and techniques were not formally compiled nor written down. My task was to create an agroforestry guide that would outline all of these concepts and contextualize them in terms of the environment. Ultimately, I produced a 100 page guide (Bird, 2013), half of which was devoted to providing information about basic environmental science concepts such as the water cycle, pollution, deforestation, soil, and many others. The second half was devoted to describing the agroforestry program and its many components. The guide, of which 25 copies are being used in Chikuni, are intended to serve as the foundation for the eventual and professional creation of a formal agroforestry curriculum. As a result of having this guide produced, the Chikuni Mission was able to secure funding for the development of such a curriculum.

I lived in Chikuni for 50 days and travelled to over half of the IRI schools to conduct research for the guide. During the process of creating the agroforestry guide, I was exposed to a variety of issues that were far beyond the scope of my research for the Global Social Benefit Fellowship. Most notably was the energy, climate, poverty nexus that I explored piece by piece during the 50 days I was living in Zambia. It was this larger issue that served as the genesis for this paper and although I did not initially intend to conduct research toward this end, the resources and networks I was connected to in Chikuni enabled me to do so.

II. Methodology

The most important resource in terms of creating the agroforestry guide and conducting the research for this paper was Boniface Hangala. Boniface was born about 30 km from Chikuni and grew up in the area. In addition to having tremendous indigenous knowledge, Boniface is one of the few people in the area to receive a college degree, in this case from The Zambian College of Agriculture. Even more rare is the fact that he stayed in the area, although it would have been quite easy for him to find employment in Lusaka or elsewhere in the world. Boniface serves as the Agroforestry Technician for the Taonga office and is one of the senior administrators there. Boniface is primarily responsible for the establishment of the agroforestry program in Chikuni and has overseen the construction of every garden at each of the IRI schools. Aside from directing the creation and development of these gardens, Boniface is in charge of teaching the students and community members the various aspects of the program itself. He serves as the primary agroforestry teacher at each of the schools although some schools have designated agroforestry mentors who conduct lessons and maintenance in the gardens. Boniface is a tremendous asset to the Taonga office in that he possesses a unique blend of indigenous knowledge, formal education, and local experience.

Boniface was the key informant for this project and he served not only as my mentor and guide, but also as my translator for most interviews. During the 50 days I was living in Chikuni, I travelled on the back of Boniface's motorbike each time he went out to check on the gardens or conduct lessons. The research for the agroforestry program was based on preparations I had made prior to departing for Zambia. Essentially, I was attempting to gather information regarding each component of the program and compile it into a guide. I based the design of the guide on a variety of studies conducted regarding agroforestry education (Asare, 1990; Dixon et al, 2001; Kwesiga et al, 2003; Rudebjer et al 2002; Sumner, 2008). Eventually, the scope of this research grew beyond the simple

creation of an agroforestry guide and developed into what is presented here in this paper. Therefore the research design shifted dramatically during the course of my stay in Zambia. This shift was facilitated by Dr. Emile McAnany, emeritus professor of Santa Clara University's Communications Department. Dr. McAnany has several decades of experience working in the developing world and has worked extensively with IRI models, using various techniques ranging from formal interviews to dynamic participant observation.[1] Dr. McAnany was with me in Chikuni for 3 weeks and served as in invaluable mentor.

Although the original methods I had prepared while in the US were no longer sufficient, I was able to take much of what I had prepared and adjust this to a revised methodology for obtaining the information presented here. While this transition was organic and never formalized, it can be described as a version of dynamic participant observation (PO) with four major components, all of which helped to inform this research (Loftand et al, 2006). It is from this PO structure that nearly all of the information presented in this paper was obtained. The findings are presented in a holistic way that is reflective of this dynamic method of research.

The first component of the PO I conducted in Chikuni involved one-on-one interviews with Boniface specifically regarding the agroforestry program. I conducted three of these interviews, which ranged from one to two hours, at the Taonga office. During the first interview, we outlined the different components of the agroforestry program. We began with how to site a garden and then moved into topics such as soil measurements, water resources, living fence and nursery construction, mulching, planting, transplanting, harvesting, storing crops and seeds, and finally marketing and selling produce. The second session was spent fleshing out these different components so that I could write the guide in such as way that one would be able to follow it and understand the main features of one of Taonga's agroforestry gardens. The final interview involved a discussion about the main plant species that are incorporated into the agroforestry garden along with their ecological, social, and economic benefits. This first component of the PO model was the most valuable in terms of understanding the versatility of the agroforestry program developed by Boniface and Taonga. It is from these interviews that the majority of the information regarding the agroforestry intervention (described under the virtuous cycle) is drawn.

The second component of the PO involved semi-structured interviews with various individuals in the area. These interviews were conducted with over 60 people including farmers, parents of schoolchildren, IRI mentors, charcoal middlemen, and charcoal producers. These interviews largely focused on issues surrounding energy poverty and environmental degradation. Questions from these interviews included 1) have you noticed anything different about the forests compared to the past five or ten years? 2) Have you noticed anything different about your farm compared to the past five or ten years? 3) Are you planting trees to replace the ones you cut down for firewood/charcoal? These questions often inspired other improvised questions that I asked to follow up on anything interesting. To keep the questions short and consistent, Dr. McAnany and I determined that the questions should be yes or no based, or at least require very simple answers. This, along with the fact that I was receiving translations

[1] More information about Dr. McAnany can be viewed at http://www.scu.edu/profiles/?p=5343

from Boniface during these interviews, is why no full quotes are given in this paper. Rather, summaries of what was translated by Boniface for me are presented. Dr. McAnany and I also discussed the use of recording devices during these interviews. The use of these devices was deemed unsuitable for this project because it might make some interviewees uncomfortable. The data from these interviews informed much of the narrative of this paper and helped me to paint a picture of how charcoal production is affecting the lives of the people of Southern Zambia.

The third component of the PO model involved semi-formal participant observation at the different sites including gardens, the Taonga office, farms, charcoal production areas, and schools. These observations allowed me to see how the agroforestry program was taught to children and adults as well as understand how the Taonga office perceived Boniface's work and methods. This type of observation also allowed me to watch Boniface and others conduct their business without the distraction or potential for bias that arose when I was asking questions. Often I would stand to the side and simply watch as things unfolded. These observations occurred throughout the entirety of my stay in Zambia, the results of which can be seen in the pictures presented in this paper.

The final component of the PO model is the informal interactions I had with Boniface and others throughout the whole experience. These informal interactions were a mix of random and impromptu stories, demonstrations, and discussions I had with Boniface. Often when traveling with Boniface, we would encounter something of interest to me, which I would ask him about. Other times, we would come across some things that seemed inconsequential to me but would turn out to be of great importance to Boniface. These impromptu, informal interactions are presented in the narrative component as well as in the analyses. Although not formalized, these interactions were perhaps the most significant and memorable to me in terms of understanding the complexities and intricacies of the energy, poverty, climate nexus.

III. The Vicious Cycle

The day began as usual with the sound of roosters and barking dogs, followed by a cup of mediocre instant coffee and dusty walk to the office where I was to meet Boniface Hangala, my guide and mentor. Thus far, he had taken me to see three or four the 19 school gardens, although from what I had seen they looked more like barren plots of land with crudely constructed fences than the productive and thriving gardens I had been expecting. We were scheduled to visit Nakabwe, one of the most distant centers from our base in Chikuni. While I waited for Boniface, one of the members of the Taonga staff joked that even after six years of working there, he had never been to Nakabwe. When Boniface finally arrived on the sputtering motorbike, I struggled to get out a greeting in Tonga, the local language, before clambering onto the back of the bike.

After about 11 kilometers I began to understand why the man at the office had never been to Nakabwe. We weren't even halfway there and already the road had become rocky and unstable, our motorbike kicking up a cloud of white dust as we went along. What had begun as slight hills turned to steep pitches, forcing us to get off at times and push the bike. After a few more kilometers of bumpy riding, we arrived at the top of a hill where Boniface parked the motorbike. He dismounted and walked over to side of the road while I took in the sights. Surrounding us was a hilly landscape with a few small

shrubs and scraggly trees. In the valleys between the hills I could see where the rains had carved small canyons into the hills, taking what must have been tons of soils with it.

Boniface beckoned me over and pointed at the adjacent hill. His usual grin had been replaced with a solemn look. The hillside had recently had about an acre of trees cut, all of which now littered the ground, grey and dying, marking the hill like a scar. "Its just...so painful" Boniface said. As we gazed out, he spoke of a time when the hills of Nakabwe were covered in forests characterized by tall, spreading trees, and dense thickets. The air that was now dry and hot was once cooler and full of the scent of the forest. Boniface sighed and kicked a nearby stump. "This tree would have been 100 years old" he said, "now gone. Gone for charcoal." The stump was the butchered remains of a *Mu'umba* tree, normally a beautiful hardwood tree with a spreading canopy. This was one of many stumps that could be seen scattered about the landscape.

We returned to the motorbike and travelled down to the bottom of the valley. Off to the side of the road we could see a group of people sitting idly on the hill. Boniface called down to them, likely explaining why he had brought a *mazungu* so far out into the country. We then walked down and greeted what turned out to be a family of charcoal producers. They sat around a smoldering, heap of dirt, from which the smell of burning wood emanated. Boniface translated as I asked the man some questions about the economics and motivations behind charcoal production. When I had finished I walked around the heap taking pictures of the scene and stopping briefly to wave at the children who had stopped playing to stare at me with wide eyes and open mouths (Exhibit 3). They had been playing with briquettes of charcoal from the previous batch the family had made. Boniface walked over to me and said "I cannot be angry with them. They just don't know what else to do." Indeed, he was correct. This family was one of many who were caught in a vicious cycle that had compelled them to begin producing charcoal.

Before describing this vicious cycle, it is worth noting how it was set in motion. The under resourced government in Zambia, like many in the developing world, is primarily concerned with driving economic growth in urban centers. Cities are seen as economic hubs and monuments to progress and there exists a tacit policy bias against rural development. While it is true that cities may drive the formal economic sector in many of these countries, policies that neglect rural areas in turn create markets that impoverish the many communities living outside the city. Agriculture is often seen as backward and receives less attention than industrialization programs, leaving rural populations with less power and influence than their urban counterparts (Bezemer & Headey, 2008). Furthermore, poor infrastructure and limited supply chain regulation means that rural farmers must deal with several middlemen to get their products to market in urban centers. With limited knowledge and access to markets, farmers are often ripped off by middlemen who take huge cuts of what would otherwise be the farmers' profits. These are just some of the ways in which policy bias can affect rural farmers and can set the vicious cycle in motion.

Beyond the urban-centric policies that may set the vicious cycle in motion, there are several factors that when combined, have accelerated and perpetuated the cycle. Perhaps the best place to begin when describing this vicious cycle, outlined in Figure 2, is with urbanization. A common thread throughout the developing world has been overwhelming migration of rural people to urban centers, which in the case of Zambia is the capital, Lusaka. Over the next several decades the majority of population growth in

the developing world will occur in urban settlements. Unfortunately, the rate of urbanization exceeds the rate of development, meaning that cities are unable to provide the services that their increasingly large populations require (Cohen, 2006). One of the most challenging services to provide is energy due to the high costs associated with its capital costs, fuel, and infrastructure. Lusaka is no exception; it experiences rolling blackouts and 'loadshedding', whereby the government purposely shuts off electric utilities to certain areas of the city on a regular basis to save energy.

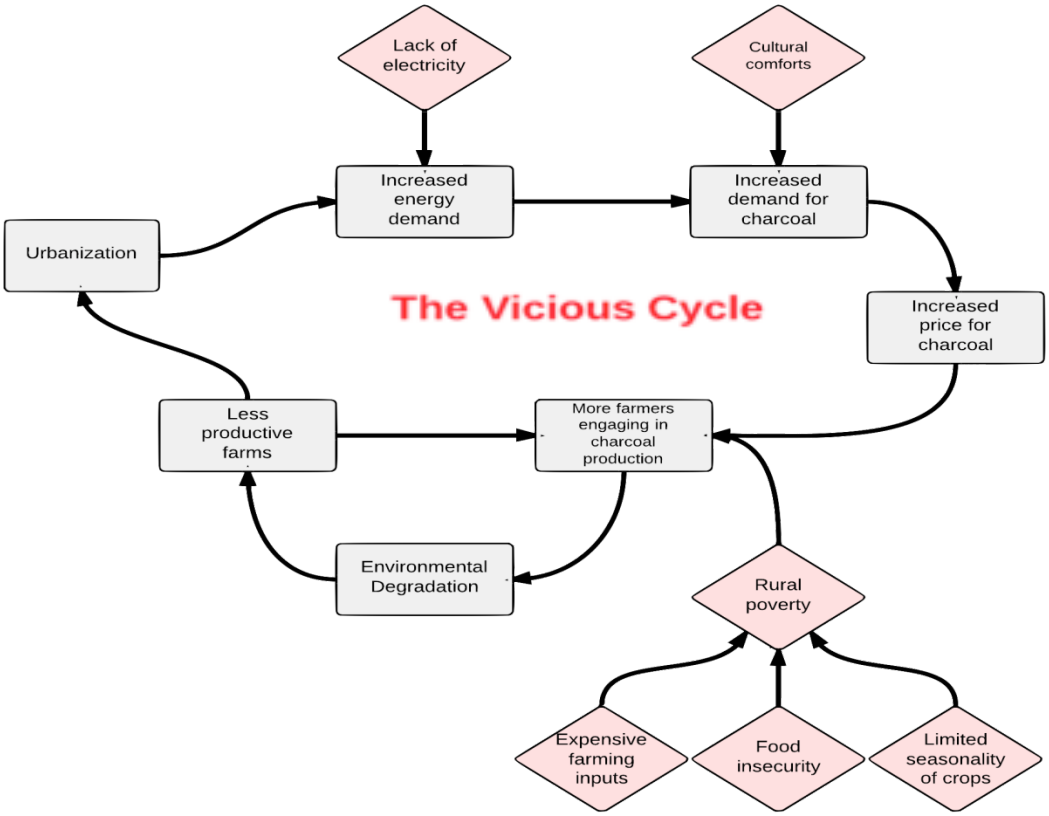

Figure 2. The vicious cycle with components in grey and drivers in red.

The increased population growth of Lusaka has resulted in increased demand for energy and a resultant energy deficit. In 2009, Lusaka had a population of 1.4 million with a rate of urbanization of 4.15%, which is in the top 20 highest rates of urbanization in the world (CIA World Factbook, 2014). While it may be possible for families to get by without a source of light when these blackouts occur, it is far more difficult to survive without a consistent energy source for cooking. Because electricity is in many cases not an option and firewood is nearly impossible to procure in the city, people are forced to turn to charcoal. It is not only the lack of electricity, however, that drives the demand for charcoal in Lusaka. Cooking over a fire or coals is the cultural norm and has been for generations. Even if electricity could be spared to provide energy for cooking, many people would still prefer to use charcoal because it represents a cultural comfort and norm. The combination of population growth in Lusaka, the lack of firewood and electricity, and the cultural aspects associated with cooking in Zambia has resulted in a massive demand for charcoal in urban areas. It is estimated that in many African cities,

every 1% increase in population leads to a 14% increase in charcoal consumption (Hosier et al., 1993). Every day, countless truckloads of charcoal are brought into the city. In Misisi, one of Lusaka's poorest (?) urban townships, children can be found playing on mountains of charcoal, where bags the size of small vehicles are piled together, ready to be distributed and sold.

Over the past few decades, the price of charcoal has been driven up as a result of the increasing demand in Lusaka and other urban centers. These higher prices have had a dramatic impact on rural livelihoods. Charcoal sellers are a common sight all along the road from Lusaka to the rural areas. These people are just one link in a supply chain that stretches from the busiest and most crowded neighborhoods in the city to the most remote areas of the country in places like Nakabwe. Although the overwhelming majority of people living in rural Zambia rely on agriculture for their income and survival, over the past few decades, the increasing price of charcoal has made it a very lucrative source of income, relative to what a farmer can glean from his crops. In places like Nakabwe, where rocky soils and steep topography limit the viability of agriculture, people traditionally foraged for mushrooms and tubers that grew well in the dense forests. As with farming, however, charcoal has also displaced this as a way of life in the area. Nakabwe is just one example of a rural area that has seen a major shift toward the production of charcoal and a disruption of traditional livelihood activities. Although the production of charcoal occurs in rural areas, it is consumed primarily in urban centers due to the fact that firewood is still the main source of cooking fuel for rural inhabitants, although as will be shown, there is less and less firewood to be found as a result of charcoal production.

There are a many reasons for the shift from agriculture to charcoal production, but the main cause is rural poverty. The current farming paradigm presents a variety of issues that many farmers seek to overcome through the production of charcoal. First, a charcoal producer can generate a substantially higher income from charcoal production than from a conventional farm because charcoal takes less physical effort and is faster to produce. Second, the current agricultural paradigm in the region revolves around the use of synthetic inputs, specialized or modified seed varieties, and chemical pesticides. The introduction of these farming techniques was an attempt to bring the Green Revolution to Africa. Although the green revolution in Africa did not see nearly the same level of success as it did in Latin America and Asia (Pretty et al., 2011), many of the practices stuck. The resulting agricultural paradigm in Zambia is a combination of Green Revolution technologies and traditional farming strategies. Unfortunately, this has largely displaced indigenous methods and has resulted in a general sense amongst farmers that without things like petrochemical fertilizers and pesticides, a successful harvest cannot be achieved. Therefore, farmers operating under this paradigm must purchase expensive inputs. Third, unlike crops, which are limited by their seasonality, charcoal can be produced year round. Finally, rural farmers are also faced with the decision of whether to sell their produce or keep it to feed their families. A farmer who can supplement the income from crops with the production of charcoal will have better food security. While most charcoal producers do not rely solely on charcoal as their primary source of income, it is easy to see why many are choosing to engage in charcoal production to help relieve some of the issues surrounding rural poverty and the conventional agricultural paradigm.

From a short-term economic perspective, these farmers are making what would seem to be a simple and rational decision.

The process for producing charcoal is also quite simple and far less labor intensive when compared to agriculture. Again, charcoal production can be engaged throughout the year and offers a lucrative supplement to agricultural activities. The best trees for creating charcoal are the large Zambian hardwoods that are decades old. These trees produce a dense charcoal that burns slower. Unfortunately, these hardwoods are slow growing (Girard, 2002). The trees are cut down and chopped into smaller pieces and then stacked tightly together (Exhibit 4). This heap is then covered with dirt that is tightly packed (Exhibit 5). Depending on wind direction, a hole will be left uncovered to capture the fresh air. This is where the fire is placed to begin the pyrolysis process, or the slow burning in the absence of oxygen. Once the fire has begun, the hole is plugged and the charcoal begins to burn with limited oxygen. As the wood slowly burns, holes begin to appear on the sides of the heap. The charcoal producer works for the entire burning process to fill these holes to prevent that too much oxygen entering the heap. Depending on the size of the heap, the burning may take anywhere from a few days to over a week. When the burning process is complete, the logs are uncovered and any remaining fire is extinguished. Then the logs are covered again for another few days to allow them to cool and harden. Finally, the briquettes are ready to be bagged and sold. All told, the process takes anywhere from two to four weeks from cutting trees to bagging the briquettes.

Unfortunately, the unsustainable production of charcoal has many severe environmental ramifications. The most serious of these is large-scale deforestation. Part of the reason why the harvesting of tubers and mushrooms in Nakabwe has ceased to be a viable source of income is that massive deforestation in the area has dramatically thinned out the once dense forests that allowed mushrooms and tubers to grow. But this is only one of the many negative side-effects of deforestation. Areas that were once heavily forested with large, old trees, are now barren landscapes with only a few trees remaining. A single charcoal producer can easily clear over an acre of land just to make charcoal, meaning that deforestation is occurring at an alarming rate. In just a few decades, the region has seen many of its forests almost completely disappear.

The effects of deforestation on the environment are a serious concern. Erosion and the loss of topsoil have become major issues because without trees to slow the wind and capture rainfall, the earth is washed away at a much higher rate than normal. Loss of forests increases wind speeds, which can contribute to the destruction of buildings and the spread of fires. Fires, in turn, prevent new trees from growing back to replace those that have been cut down. Temperatures in the area have also become increasingly volatile, occasionally resulting in frosts that kill off crops, destroying entire harvests and worsening the condition of farmers.

Additionally, the process of producing charcoal destroys the soil where the charcoal is made. After the charcoal is dug out of the heap of dirt, what is left is a patch of compacted dirt and char that is toxic to new plants (Exhibit 6). The process is also dangerous to the producers themselves. While the process is relatively fast, the producers must tend to the heap for up to two weeks, thus exposing themselves and their family members to the toxic fumes that come from pyrolysis such as carbon monoxide.

The environmental degradation caused by the production of charcoal serves to perpetuate the vicious cycle for several reasons. As topsoil is washed away, wind speeds

pick up, and temperatures become more extreme, farms become less productive. Less productive farms exacerbate rural poverty either by reducing a farmers' potential income or by causing the farmer to spend more on expensive inputs to try and compensate for the reduced productivity. Less productive farms also result in less food security and more pressure on farmers to produce charcoal to supplement their depressed incomes. While this is a miniature vicious cycle in itself, the ultimate completion of the larger vicious cycle occurs when farmers who are unable to provide for themselves in rural areas move to the city for better opportunity, thus increasing urbanization and beginning the cycle all over.

Unfortunately, one of the largest drivers for the vicious cycle is the lack of understanding among many rural inhabitants regarding the long-term relationship between charcoal production and environmental degradation. A rural farmer who may not be educated, may find it difficult to grasp that cutting down a few trees for charcoal to make up for a poor harvest may, in fact, be the cause of the poor harvest. Again, from a short-term perspective, these farmers are making rational decisions. The disconnect is quite apparent in that when asked about their perceptions regarding the availability of wood resources, most of the interviewees indicated that they had noticed that they were having to travel further from their home to find firewood or trees to make charcoal. When asked if they were replanting trees to replace the ones they were cutting down, the majority of respondents said no. This can be attributable both to a lack of access to seeds and knowledge about tree planting, but it is also caused by a lack of understanding about sustainable forest management.

The wide-ranging effects of climate change will make it more difficult for forests to grow back on their own, making it even more imperative that the existing forest resources are protected. More frequent and extended droughts will make it more difficult for young seedlings to become established. Combine an extremely dry habitat with higher wind speeds and fires become a major threat, tearing through the countryside, decimating any seedlings that are attempting to grow back. Climate models also predict an increase in the frequency of intense rainstorms and extreme weather in Zambia on top of a projected increase in droughts (IPCC, 2007). Heavy rainfall is only beneficial if the land can absorb the water that falls, otherwise it will wash away in flashfloods. The deforestation of the countryside means that when heavy rains fall, the trees that normally would capture and slow the runoff aren't there, resulting in massive levels of erosion (Exhibit 7). The increasing frequency of extreme weather means that frosts, like those mentioned before, will be ever more devastating without forests to regulate the temperature. Climate change will continue to take its toll on the resiliency of the natural world, meaning that if nothing is done to reduce the heavy deforestation that is occurring in Zambia, it is unlikely that the once dense forests will ever grow back. If this were to happen, the livelihoods of rural inhabitants would be threatened even further and the vicious cycle might, in fact, become a permanent reality.

IV. The Virtuous Cycle

Boniface and I shook hands with the charcoal producer and his family and thanked them for their time before walking back up the steep hill to the motorbike. We continued traveling through the seemingly desolate hills and dusty roads of Nakabwe

with the sun beating down from above. It was hard to imagine that just a decade ago, the only paths through these hills were small foot trails that twisted through the dense, dark forests. I became keenly aware of how many tree stumps and patches of blackened earth littered the landscape, each like a gravestone marking the death of an ancient tree. I began to consider what would become of Nakabwe in the future. Once the full effects of widespread deforestation set in, what little soils were left would be blown or washed away by strong winds and flashfloods. Fires, spurred on by fast winds would destroy whatever young trees were trying to grow back. What was once a beautiful, healthy forest would be turned into a barren landscape with nothing left to offer the already desperate farmers. These thoughts bounced around my head for the remainder of the ride to our final destination, Nakabwe.

After parking the motorbike at the top of a hill, we descended down the opposite side along a wide road. As we walked, Boniface described the many difficulties of building a garden in the hills around Nakabwe. Rocky soil, deep groundwater, and the slope of the land were all serious impediments. I listened and began to expect the worst as we continued along. The road narrowed and we came to a line of trees. "*Gliricidia sepium*" Boniface said casually, lightly fingering some of the small leaves. He never ceased to impress me with his botanical expertise. He stepped into the trees and over a small fence of piled logs. I followed suit, keeping my eyes down so as not to trip.

As we moved through the shade of trees, the air became cooler and I caught the musky scent of decomposing plant litter. On the other side of the trees was a world so markedly different than the one we had just came from that I was left in disbelief. What lay before me was a lush garden, bursting with every shade of green imaginable. The borehole pump was a few feet away; water dripping from its spout into a sparkling puddle above which giant white bumble bees buzzed lazily. Rows of trees and plants were laid out, creating pillars and hallways within the garden. I stood in speckled sunlight under the canopy of a fully-grown *Jatropha* plant, looking at the wondrous display before me. Rather than the desolation I had been picturing a moment before, I now saw life flourishing.

Boniface showed me around the garden, pausing to describe its many features, each of which contributed to the synergy and health of the many other components. Multipurpose plants like the *Gliricidia* we had emerged from served as fertilizer trees and provided animal fodder and a fast growing source of firewood. A ring of *Jatropha* trees served as a solid 'living fence' that protected the garden as well as providing seeds that could be converted to bio-oils and sold. *Moringa*, which fertilizes the soil and can be ground into a nutritional powder packed with nutrients found in spinach, milk, bananas, carrots, oranges, and yogurt. Other plants in the garden could be used to cure ailments, create strong fibers, develop natural pesticides, and serve as a home for bees and other pollinators.

The garden at Nakabwe was indeed a beautiful thing to behold (Exhibit 8), but the implications of such a design extend beyond the confines of the *Jatropha* trees. The vicious cycle has many different components and drivers that come from a variety of social, political, environmental, and economic conditions that are present in Zambia. Policy efforts could be made to target urban energy poverty, regulate deforestation, or provide food aid, but it is likely that these efforts would be too large and too expensive to be realistically undertaken by the Zambian government or any other organization for that

matter. Furthermore, targeting any one component or driver may only divert the problem or plunge subsequent components deeper into despair. For instance, banning or regulating illegal logging may benefit the environment, but would do little to improve the livelihoods of rural farmers or solve the urban energy crisis.

Therefore, the strategy for addressing this vicious cycle must be multifaceted and aimed at several drivers and components. The strategy being pursued by Boniface and others in the Chikuni is referred to as agroforestry, although in this context, this is an oversimplification of the program, which is a mixture between no till farming, low input practices, intercropping, diversification, and the incorporation of trees into the farm. However simple sustainable agriculture may seem compared to the technologically complex and mechanized systems present in the West, it is perhaps the most complete and cost effective strategy for slowing the vicious cycle, especially from the rural perspective. The implementation of an 'agroforestry intervention' into the practices of rural farmers can dramatically alter the circumstances of both the farmer and the natural environment. As shown in Figure 3, the intervention can break the cycle at the point where increased charcoal prices incentivize rural farmers to begin producing charcoal.

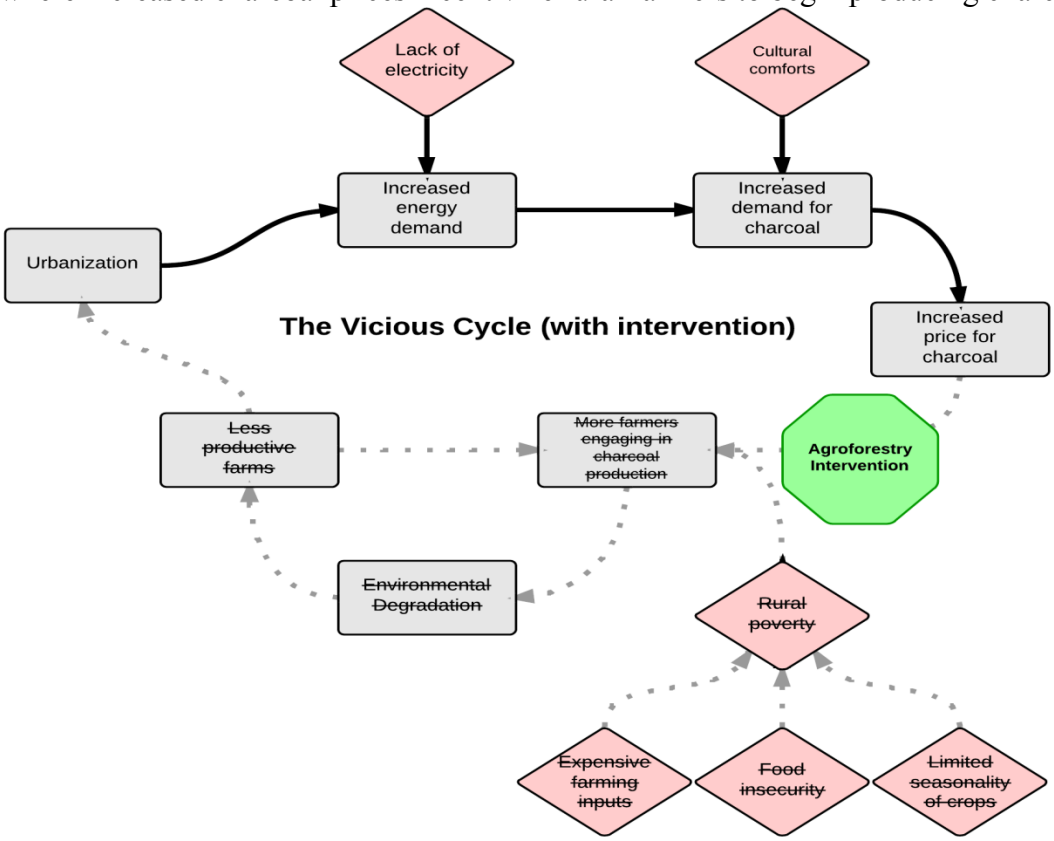

Figure 3. The location of the agroforestry intervention within the vicious cycle and the resulting reduction or elimination of certain drivers and components.

There are many ways in which the agroforestry intervention works to disrupt and ultimately replace the vicious cycle with a virtuous cycle shown in Figure 4. The remarkable thing about this strategy is that once it is fully functioning, it can simultaneously reduce or eliminate several of the drivers and components of the vicious cycle. Perhaps the best place to begin when describing the agroforestry intervention is

with how it addresses the largest driver of the vicious cycle: rural poverty. As illustrated earlier, rural poverty is a complicated reality that has many dimensions beyond what happens on the farm. Nevertheless, as the largest industry in rural Zambia, the importance of farm economics cannot be underestimated. Ultimately, it is the fact that farmers do not have to spend money on expensive seeds, inputs, and pesticides that makes the agroforestry intervention a good strategy for reducing charcoal production. Money saved on the farm is money that does not need to be supplemented by charcoal.

Table 1. Some of the various agroforestry plants and their associated ecological, social and/or economic benefits.

Species	**Farm Use**	**Social Benefit**	**Economic Benefit**
Agave sisilana (Sisal)	Living fence		Fibers can be turned into rope, self-propagating (don't need to buy new seeds)
Bidens pilosa (Blackjack)		Traditionally used to treat hypertension and kidney problems	
Cajanus cajan (Pigeon pea)	Leguminous Nitrogen fixer, compost material, soil preparation	Protein rich peas	Natural fertilizer
Casimiroa edulis (Mexican apple)	Shade tree, windbreak	Sweet fruit for consumption	Good wood for building and making tool handles
Gliricidia sepium (Quickstick)	Fertilizer, compost material, good habitat for bees, drought & temperature resistant, windbreak, firebreak		Firewood, building material, resprouts quickly (no need to replant)
Jatropha curcas	Living fence	Can produce lamp oil that is cleaner than kerosene and repels mosquitoes	Oil extract from seeds can be turned into biofuel that can be sold
Leucaena spp.	Fertilizer, compost material, windbreak		Firewood, building material, good animal fodder for more productive livestock
Moringa spp. (Drumstick)	Fertilizer, compost material	Nutritional supplement, antioxidant, rich in iron, calcium, potassium, protein, Vitamin A & C	Highly marketable as a tea or powder for food
Tephrosia spp. (Fish Poison)	Fetilizer, compost material,		Sap can be made into a potent pest repellant and can be turned to a powder to protect seeds from weevils
Sesbania spp.	Fertilizer	Traditionally used to treat urinary tract issues	Light construction material, animal fodder
Vignus unguiculata (Cowpea)	Deep rooted leguminous nitrogen fixer, low water usage	Protein rich peas	Good animal fodder for more productive livestock

The three main issues with the current agricultural paradigm that lead to rural poverty in Zambia are expensive farming inputs, the limited seasonality of crops, and food insecurity. In terms of inputs, the agroforestry intervention can essentially eliminate

the need for synthetic inputs altogether. In the case of fertilizers, one of the main pillars of the strategy is to incorporate naturally fertilizing plants. Leguminous plants such as cowpeas (*Vigna unguiculata*) and pigeon peas (*Cajanus cajan*) are excellent fertilizer crops that host nitrogen-fixing bacteria in their root systems. Fertilizer trees like the *Moringa* spp. and *Faidherbia albida* can boost soil fertility by dropping nutrient rich leaf litter, which can be incorporated into natural compost. In terms of pest control, the sap of some *Tephrosia* spp. can be extracted and used as a potent pest repellent, which can replace expensive chemical pesticides. The many uses associated with these plants have been explored and witnessed by Boniface, who blends scientific knowledge and indigenous understanding of how these plants can be used by farmers ecologically, socially, and economically.

The diversification of the farm is another component of the agroforestry intervention that also reduces rural poverty by targeting the limited seasonality of crops. A diversified farm means that farmers can have more than the typical three or four harvests per year as is typical under the current agricultural paradigm. A diversified farm also produces non-food crops that can be sold year round without the possibility of them rotting. Examples include the oils derived from *Jatropha curcas* seeds, or the rope fibers that can be made from *Agave sisilana*. Firewood and building materials can also be taken from the farm from trees like *Grilicidia sepium*, which grows back very fast and produces sturdy wood. The sale of these types of products is the entrepreneurial aspect of the agroforestry intervention and has the potential to completely restructure how farmers generate income. Some of the many plants that can be used for the agroforestry intervention are displayed in Table 1.

Finally, the agroforestry intervention incorporates a variety of other crops that diversify the foods eaten by the farmer beyond the traditional corn diet and boost the nutrition. The *Moringa* spp. leaves can be crushed into a powder that can be sprinkled on top of any food to serve as a nutritional supplement, while plants like cowpeas and other legumes are rich in protein. These nutritious plants can also be used as animal fodder, which in turn keeps livestock healthier and generates richer animal produce. The agroforestry intervention also incorporates techniques that maximize the use of space within the garden. Intercropping is one such technique that can take full advantage of the nutrients within the soil and save space. For instance, growing *Moringa* spp. with cabbage or tomatoes can not only improve the soil as discussed before, but can also provide a farmer with double the harvestable material. The more produce that can be grown on a certain amount of land, the more food the farmer has to sell once the family's dietary requirements have been met.

While the versatility of the agroforestry intervention, shown in its entirety in Figure 4, is extraordinary in terms of addressing rural poverty as a driver of the vicious cycle, it has other benefits as well. The second most important facet of the vicious cycle is the environmental degradation that takes place as a result of charcoal production and unsustainable farming techniques. As discussed before, the production of charcoal leads to widespread deforestation, which results in faster winds, volatile temperatures, erosion,

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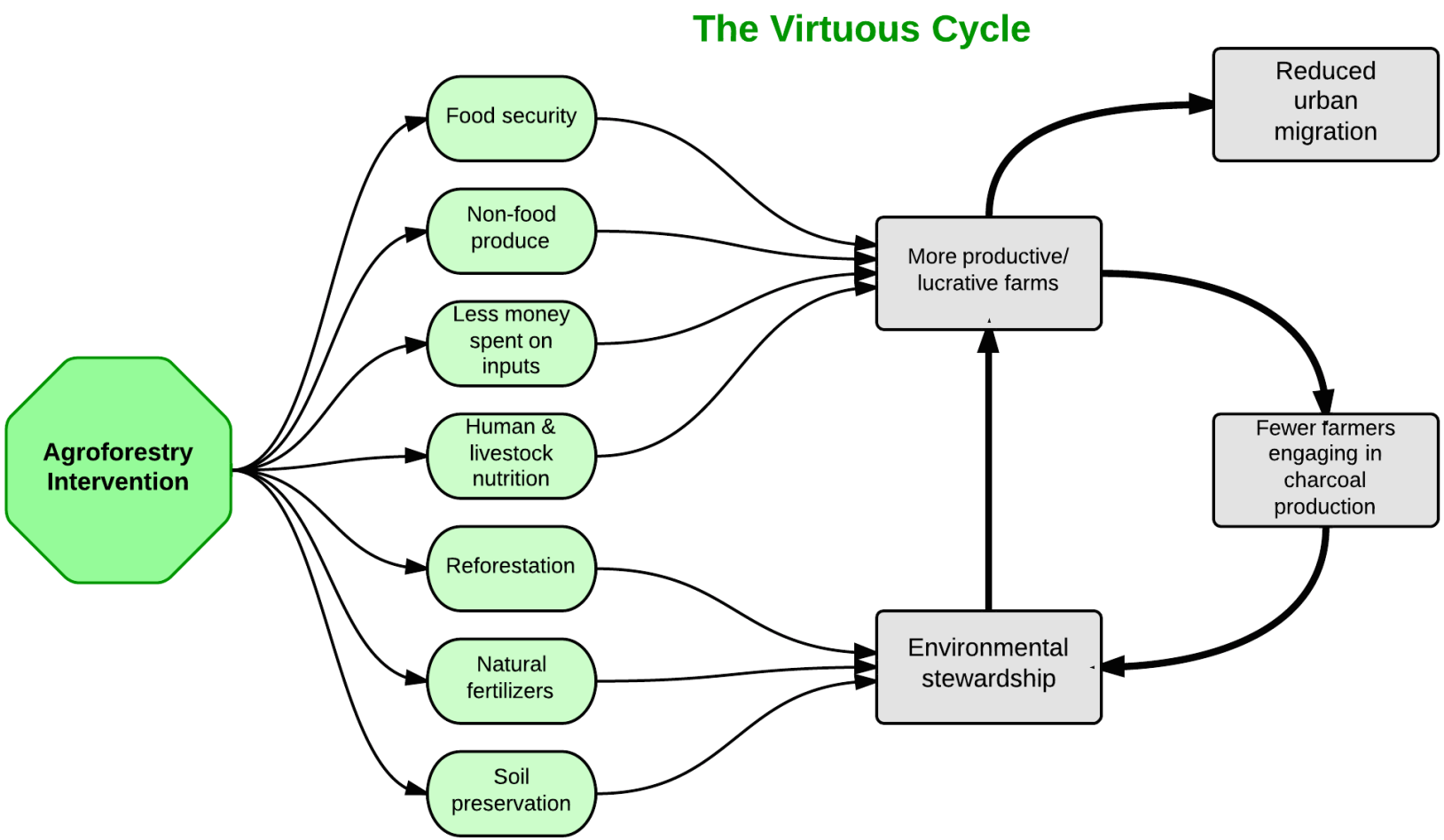

Figure 4. The agroforestry intervention and the subsequent introduction of the virtuous cycle as an alternative to the vicious cycle.

loss of habitat and a handful of other serious issues. The agroforestry intervention addresses deforestation in two ways.

The first is simply that if farmers can develop more productive farms that meet their dietary needs and allow them to engage in income generating activities, such as the sale of produce or other products, they will have less reason to continue producing or begin producing charcoal. Most rural Zambians do not rely entirely on charcoal for their income, but rather as a way to supplement what their farms produce. Therefore, the choice is simply to stop producing charcoal and focus on the now more productive farm.

The second way in which the agroforestry intervention addresses deforestation is by reversing some of the effects. The basic concept of agroforestry is the incorporation of trees with farms. Under this scheme, however, trees are incorporated for other purposes beyond the health of the farm. For instance, under ideal circumstances, farmers would not just use *Gliricidia* as a fertilizer tree in the farm, but would create long rows of these trees that spanned 100 yards or so. The benefit of these tree rows is that they serve to stabilize soil, slow the wind, and provide a firebreak (*Gliricidia* is largely fire resistant). Furthermore, this species can be planted in close proximity, producing straight and sturdy wood. The plant also grows very quickly, even when re-sprouting after being cut to the ground meaning that if enough trees are planted, they can be sustainably harvested to supply the farmer with firewood/building wood throughout the year without having to be replanted. If a large number of rural farmers began planting such rows of trees, the degradation caused by over a decade of heavy deforestation would start to be reversed. Ultimately these results could lead to a virtuous cycle that reverses some of the deleterious effects of deforestation and drive positive environmental and social outcomes.

One of the largest challenges is that farmers, even if they adopt the agroforestry intervention, might continue to produce charcoal. Charcoal production is a direct process compared to agroforestry and the opportunity cost in terms of time and labor of engaging in charcoal production is far lower than that of agroforestry. It is important to recognize, however, that charcoal has only recently become a major issue in Zambia. Only in the past decade or so have the environmental ramifications of charcoal production become as severe as they are, meaning that people survived for centuries without this non-traditional source of income. Furthermore, in many cases, turning to charcoal production is an act of desperation. For instance, in an interview I conducted with a man named Kingsley, who is a charcoal middleman, I discovered that his involvement with charcoal was the result of losing both of his parents at a young age and not having the capability to maintain the family farm and provide for his brothers and sisters. He also explained that the process of producing, packaging, transporting, and selling charcoal is time intensive process. In order to sell his charcoal, Kingsley had to make several trips of over 10 kilometers to the nearest urban center.

The virtuous cycle comes full circle when the responsible management of the environment results in more productive farms, which would no longer have to contend with large temperature fluctuations, high winds, erosion, and fire. These productive farms and the associated forestation techniques could one day return the region to an ecologically flourishing and prosperous area, lifting individuals out of poverty and reducing their dependence on unsustainable practices such as charcoal and conventional farming. There is also the possibility that a stable rural environment would reduce urban migration and effect change in the urban centers as well. This type of widespread change

can only be possible if the agroforestry intervention is adopted on a large scale. In other words, the environmental benefits of reforestation, wind breaks, low input agriculture and the other tenets of the program will not be realized if only a few people adopt them. One of the questions I posed to farmers and charcoal producers in the area was whether they felt that they should be replanting trees. Many of them indicated that they would if they had the knowledge of how to do so.

After sharing an apple in the shade of the garden, Boniface and I returned to the motorbike to begin the long ride home. As we rode back through the hills of Nakabwe toward Chikuni, I was struck by the potential for such an intervention to radically alter the circumstances of the people living here and elsewhere in rural Zambia. If in Nakabwe, one of the most difficult areas to build a farm and the most heavily affected by charcoal production, could harbor an Eden such as the one we had just left, then areas more conducive to farming could benefit even more. We passed the charcoal producer and his family who waved to us as we rode by. I recall hoping that the children who were now playing with briquettes of charcoal would raise their own children in the shade of a flourishing farm, free from the destructive practice of charcoal production, teaching them to create a sustainable, prosperous garden of their own.

V. Conclusion

The problems associated with widespread charcoal production extend far beyond the possibility of a permanent loss of forest resources. Although deforestation has a variety of negative impacts on the larger environment, including erosion, increased wind speeds, and temperature fluctuations, the environment is not the only factor to consider. All of these problems cause rural farms to become less productive, which further exacerbates rural poverty, thus forcing some farmers to begin producing charcoal to supplement their incomes. This vicious cycle, however, can be halted by an agroforestry intervention, which addresses rural poverty and promotes environmental stewardship, thus creating a virtuous cycle that allows farmers to improve their livelihoods and avoid producing charcoal.

Although the virtuous cycle is a robust and comprehensive strategy for addressing the rural aspects of the energy, climate, poverty nexus, it is not a complete solution. One of the main issues with this strategy is that it does not address urban demand for energy, which is one of the primary divers of the vicious cycle. At best, the agroforestry intervention has the potential to slow urban migration and thus prevent the demand for charcoal from growing at such an alarming rate. What is truly needed is an urban energy solution. Indeed, it is unlikely that charcoal will be replaced entirely as a fuel source in African cities in the near future. Therefore, the focus should be on promoting affordable and sustainable distributed energy technologies that can make up part of the electricity deficit in urban centers. Clean cook stoves that use other fuel sources or improve the efficiency of charcoal fuel should also continue to be developed and implemented. Biogas and ethanol could serve as viable replacements for charcoal that would not disrupt the cultural cooking norms. If charcoal is to remain a major fuel source, governments and other agencies should ensure that their forests are managed sustainably such that the rate of deforestation is significantly reduced. This may require governments to put more resources into protecting their national forests and parks, which cover approximately 30%

of the country (Zambia Tourism, 2014). Like many African parks, many of Zambia's parkss are poorly enforced and as a result, charcoal producers are able to remove forest resources without impediment.

Future research is needed to determine the best way to disseminate knowledge regarding the agroforestry intervention. This is a major barrier to the implementation of these technologies and is an essential component of this strategy that was not researched for this paper. Chikuni relies almost exclusively on Boniface to teach community members and children about agroforestry practices, which is neither feasible nor sustainable in the long run. The Zambian government can play a major role in the implementation of these technologies if they can muster the resources to produce a formal guide or curriculum that can be implemented nationwide. As mentioned before, the Zambian government successfully created a manual to help make charcoal production more efficient, and that effort can serve as a model for the creation of an agroforestry manual. Unfortunately, the government is under resourced and would likely need outside help and funding from NGOs or development agencies to create this type of guide. Another potential method for education is the 'hub-and-spoke' model, whereby large demonstrations are held at established and centralized locations while outreach teams of trained technicians reach out to more isolated communities to spread the word and help with any maintenance. Innovative technologies like the radio program operated by the Chikuni Jesuit Mission is another way to reach isolated populations.

Perhaps the largest barrier, as mentioned before, is that the value of the agroforestry intervention can only be fully realized if the techniques are implemented on a large enough scale to combat the widespread destruction caused by deforestation. Entire villages must adopt these practices in order for the benefits to be realized on a larger environmental scale. Nevertheless, the agroforestry intervention remains one of the most complete strategies that empowers farmers in an inexpensive and sustainable manner and has the potential to become the centerpiece for rural development programs in Zambia and across Sub-Saharan Africa.

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Appendix

Exhibit 1. The IRI school at Cheelo, constructed by the community and served by the Chikuni Mission.

Exhibit 2. One of the least developed IRI schools being directed by a mentor in the shade of a tree at Hakalinda.

Exhibit 3. Children of one of the charcoal producing families I met with, playing with the latest batch of charcoal.

Exhibit 4. A small heap of logs ready to be covered and turned to charcoal.

Exhibit 5. A large charcoal heap, likely to produce 200 small bags of charcoal.

Exhibit 6. The remnants of a charcoal heap, leaving the ground scorched and poisoned, unable to support plant life.

Exhibit 7. The result of heavy erosion in a deforested region. The left side of this bridge has been completely filled in with eroded soil.

Exhibit 8. The thriving garden at the IRI school in Nakabwe with a fully-grown living fence of *Jatropha* trees on the right and a grove of *Moringa* on the left side.