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Diffusing Chinese rice
technology in rural
Tanzania:
Lessons from the
Dakawa agro-technology
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ABSTRACT

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DURING THE BEIJING SUMMIT of the Forum on China-Africa Cooperation in 2006, the Chinese government pledged to build 10 agro-technology demonstration centers across Africa. Since then, the figure has increased to 25 and it will likely increase again in the future. One of the main goals of the demonstration centers is to share the experience of China's technology-driven agricultural modernization with African countries. This paper uses empirical evidence from the Dakawa center in Tanzania to examine the role of these centers in diffusing selected agro-technologies to local farmers. The Dakawa center has struggled to balance the goal of technological diffusion with other interests, most notably the manifestation of China's soft power and its commercial goal of operating a financially self-sustaining farm. Yet, despite these broad ambitions, the center has managed to contribute a great deal towards multi-actor efforts to lessen the information and knowledge barriers hindering the adoption of improved rice farming technology by farmers in Dakawa. Other barriers to technology adoption, including financial constraints and socio-cultural ties to traditional practices, necessitate that the demonstration center improve its collaboration with other related actors.

INTRODUCTION

THROUGH A BILATERAL AGREEMENT WITH TANZANIA, the Chinese government granted an equivalent of US\$6 million to finance the construction of a Chinese agro-technology demonstration center (ATDC) from 2009 to 2011. The ATDC was built in the village of Dakawa, Tanzania, and operated by the Chongqing Sino-Tanzania Agricultural Development Co. Ltd in partnership with the Tanzanian Ministry of Agriculture, Food Security, and Cooperatives (MAFC). The center is equipped with a 12 hectare (ha) fenced-in area—10 hectares of which are used as an experimental field, and 2 hectares of which house a laboratory, an office complex, and training facilities. Additionally, the ATDC has 50 hectares of unfenced fields equipped with irrigation and drainage channels. The development and evolution of the ATDC has involved three phases: first, the construction phase; second, a three-year subsidized phase involving demonstration, training, and extension services; and the third phase is expected to cover three or upon the agreement more years of a financially self-sustained operation which combines commercial activities and services to farmers. Following completion of the construction phase in 2011, the Chinese government subsidized the Chongqing Company to operate the ATDC for three years. Moving forward into the third phase, the ATDC is meant to support itself, for example through income generating horticultural and poultry investments. It is worth noting that the first two phases of the ATDC's operations—including their historical background, construction, launching, and part of their—have been covered by literature.¹ A visit by the China-DAC study group^{*} with delegates from the Chinese government, the US government, and the Tanzanian government during the second phase, for instance, resulted in an official report on the ATDC in 2012, which emphasized the collaboration between Chinese and US agencies in Dakawa.²

Located about 250 km from the capital city of Dar es Salaam, Dakawa is one of Tanzania's major areas of rice production. The village has a major paddy irrigation scheme, which was previously owned by the state before being transferred to a smallholder cooperative. In addition to the ATDC, several other development agencies with interest in diffusing modern rice technologies have served Dakawa, including the International Rice Research Institute, Africa Rice Research, and the World Bank.³ Dakawa is also home to a public rice research station, Cholima, as well as rice milling machines.

The Dakawa rice farmers have also benefited from the NAFAKA[†] project, funded by the United States Agency for International Development (USAID) under the Feed the Future program. In Tanzania this program has been managed by ACDI/VOCA, with a total budget of US\$70 million per year to increase agricultural productivity and improve the country's nutrition status.⁴ Out of this budget, the NAFAKA project was allocated with US\$34 million to improve smallholder farmer productivity and

^{*}The China-DAC Study Group was formed in 2009 to share knowledge and exchange experiences on promoting growth and reducing poverty in developing countries, and it comprises experts and officials from China and members/observers of the OECD's Development Assistance Committee (DAC). Further information on the China-DAC Study Group and its activities is available on the Internet at: www.iprcc.org or www.oecd.org/dac/cdsg

[†]Nafaka is a Swahili word for grains. The name fits the focus of the project's goal of increasing competitiveness of rice and maize value chains to improve nutrition.

profitability within the rice and maize value chains in seven regions of Tanzania, including Dakawa village. In Dakawa the project focuses on a cooperative of irrigators known as Ushirika wa Wakulima Wadogo Dakawa in Swahili (UWAWAKUDA). The cooperative receives support from NAFAKA through several capacity building channels. For example, NAFAKA assists in improving UWAWAKUDA farmers' financial capacity through savings and internal lending community groups, savings and credit cooperatives, and contract farming services. Furthermore, the project finances the rehabilitation of physical infrastructure in Dakawa, including the feeder road, the irrigation system, and buildings for UWAWAKUDA offices and staff accommodations.

This paper examines how the ATDC has influenced farmers' adoption of improved rice farming technologies. While the main focus of this study is on the Chinese ATDC in Dakawa, it draws a comparison with the NAFAKA project and USAID's interventions in the village. For example, NAFAKA's support for local agro-enterprises and rice research institutions to advance and diffuse improved technologies in rice value chains, and the project's support for training courses and peer demonstration through the farmers' field schools (FFS) scheme are compared to the ATDC's interventions in terms of their impact on farmers' adoption of improved rice farming techniques.

BACKGROUND

AFTER MADAGASCAR, TANZANIA PRODUCES THE LARGEST amount of rice in sub-Saharan Africa.⁵ With an annual production of 1.35 million tons, rice ranks as the third most important food crop in Tanzania after maize and cassava.⁶ Traditional rain-fed agriculture dominates the rice sector in Tanzania, accounting for 74 percent of the country's land for rice.⁷ This method involves small-scale farming with farms sized between 2 to 2.5 ha on average. Twenty percent of the land for rice is occupied by improved small-scale schemes, leaving only 6 percent of the rice-cultivated land for commercial large-scale farms. About 30 percent of the rice produced is kept by farmers for household consumption. Most of the rest of the produced rice is traded within the country; only a small proportion is exported.⁸ Statistics show that Tanzania imports around 5 percent of its domestically consumed rice. Although imports represent a fairly low share of total domestic consumption, the sector's production potential is reportedly under-exploited. A study by Mkathama, for example, indicated that only 3.2 percent of the area potentially suitable for rice production was utilized in 2008.⁹

Apart from challenges such as low soil fertility, high soil salinity levels, climate change-induced droughts, and unstable markets, rice farming in Tanzania is characterized by poor innovation and a limited application of improved technologies.¹⁰ The use of improved seeds is reportedly low, as farmers rely on saved harvests as their primary planting materials.¹¹ Similarly, the use of improved inputs like mineral fertilizers is reportedly below the African and global standards.¹² The poor mechanization and high consumption of labor contributes to a raise in production costs and triggers price spikes above the global markets.¹³ Moreover, poor milling technologies have also compromised quality by leading to higher proportions of broken rice. The broader

impact of the weak application of technology to the rice sector is illustrated by the sector's productivity margins, recorded at 1.5 tons/ha. This level is markedly below the African average of 2.5 tons/ha as well as the 4 tons/ha produced on average by Asian farmers.¹⁴

Wilson and Lewis (2015) identify key areas of possible intervention that could enhance the contribution of technology in impacting the rice sector.¹⁵ These interventions include: the improvement of rice varieties, the improvement of rice farming systems, and the improvement of rice value chains. To achieve these improvements, developing countries like Tanzania must strengthen their domestic innovative capacity, while acquiring and adopting technologies from abroad.¹⁶ There have been scholarly debates between those who favor internal technological development efforts, and those who emphasize the importance of accessible external information resources. The latter are largely influenced by the idea of the "South-South flow of technology," which stands in contrast to the typical North-South flow of information and technology.¹⁷ South-South technology transfer posits that developing economies share amongst themselves approaches that they have learned from receiving aid and assistance in poverty reduction.¹⁸ A great benefit of such intervention has been the exchange of technologies and experiences throughout the south.¹⁹ Yet, it is not always clear whether these technologies and approaches that work in one country will work in another. This paper tests this idea by examining the efficacy of China's approach in diffusing the rural technologies in Tanzania under the ATDC.

METHODS

THIS STUDY DRAWS ON TWO ROUNDS OF FIELDWORK in Dakawa and neighboring villages, Morogoro Town, and Dar es Salaam. The first phase of the fieldwork took place in April 2015, and consisted of nine in-depth interviews and three focus groups. The in-depth interviews were administered to four farmers and five key respondents including: the manager of the ATDC, the manager of the Cholima research station, the agro-extension officer for Dakawa, and the Tanzanian government's representative at the ATDC. In this field mission, the deputy director of research and development at the MAFC was also interviewed in Dar es Salaam. In addition to the interviews, three focus group discussions were held during the first field mission involving 16 members of UWAWAKUDA. Observations were conducted on the techniques used in select stages of the rice production process by the ATDC, the Cholima station, and farmers working with NAFAKA project.

Key documents related to the ATDC, including contracts and information about trainees, were also reviewed. The official documents and unofficial literature related to the research topic were collected to complement the evidence drawn from empirical data, particularly in the forms of interviews, focus groups, and field observations. The second trip took place from mid-November to mid-December in 2015. This visit did not coincide with the rice-growing season, but nevertheless, farmers were contacted and they participated in two more focus groups of five and six participants, respectively,

and in eight in-depth interviews.²⁰ Findings from the field trials of the Chinese and local rice and maize varieties were also examined during this visit. These trials are conducted by Chinese and Tanzanian experts to test for variations in yield between the Chinese and local rice varieties, as they apply Chinese and local rice farming techniques. The researcher also had the opportunity to participate in the Dakawa Irrigators Association's activities, including their annual meeting. Respondent farmers were selected from the list offered by UWAWAKUDA and the Dakawa village government. A combination of random selection and convenience sampling was used. The depth of interviews and field observations limited the number of respondent farmers to 39, making it difficult to qualify the sample as a representative one.²¹ Additionally, out of these respondent farmers, 12 were female.

This case study uses ethnographic tools to examine the diffusion of technology among the rice farmers, and is primarily guided by Rogers' theory on diffusion of innovations, explained in the next section. Rogers' theory is used as a foundation to map the ATDC's efforts to promote farmers' access to and use of information about improved rice farming technology; its influence on farmers' behavior; and its overall impact on the adoption of rice farming technologies.²²

By definition, a theory of change (TOC) provides a comprehensive description and illustration of how and why a desired outcome is expected to happen in a particular context. The theory of change underlying the Dakawa ATDC is relevant for assessing the roles and position of the ATDC against other actors in the Dakawa rice innovation system. We use the TOC to examine the ATDC's success at meeting its short- and long-term goals, the sustainability of its intervention, and how its programming has complemented other agricultural development interventions in Dakawa. While Rogers' diffusion theory focuses more on farmer-based and technology-embedded drivers for diffusion, the TOC of the Dakawa ATDC instead emphasizes the importance of institutional factors in displacing or complimenting the traditional rice farming system in Dakawa.²³

TECHNOLOGY DIFFUSION

THE CONCEPTUALIZATION OF THE SYSTEMIC NATURE of agricultural innovation has gradually shifted from the traditional emphasis on agricultural research in the public sector to position the farmer as the central component of a networked system and as the driver of the innovation process.²⁴ Technological solutions either evolve through market opportunities or are orchestrated by policies implemented to promote farmers' innovativeness.²⁵ Agricultural innovations are determined by networks of individuals and institutions engaged in researching, developing and diffusing innovative solutions including improved crop varieties, fertilizers, pesticides, mechanization tools and appropriate farming techniques.²⁶ At the country level this is collectively defined as the national agricultural innovation system (AIS). The AIS can also be clustered into two major components: the technology development component, which includes the public and private research systems, and the technology dissemination

component, which is formed by the public extension system and private actors dealing with the distribution and supply of agricultural products.²⁷ It is worth noting that these two components are highly interdependent, to the extent that the efforts to create modern agricultural technologies are likely to be for naught as farmers cannot access such technologies.

The research component of the Tanzanian AIS is heavily concentrated in the public sector, and it is characterized by weak funding, a lack of modern equipment and low staffing—especially when it comes to advanced skills.²⁸ These challenges are equally evident when it comes to the rice research system, as the literature suggests.²⁹ The system has remained weak, despite its notable contributions toward improving some indigenous breeds and traditional agronomic practices.³⁰ Tanzanian rice researchers have hardly exploited modern techniques and tools such as biotechnology and the hybridization of rice.³¹ Similarly, the mechanism to reproduce and distribute those improved varieties is slow and has failed to catch up with the local demand for seeds. Looking at the mechanization of the agriculture sector through application of modern tools as an example, the only contribution of the Tanzanian AIS was the prototype power tiller invented by the Tanzania Centre for Agricultural Mechanization and Rural Technology (CARMATEC). The sector is dominated by imported tractors, tillers and other powered equipment from mature markets such as Japan and the European Union (EU), and more recently from emerging economies including India and China.³²

Rogers outlines four main factors that determine the pace and intensity at which technological innovations diffuse into a social system: (1) time; (2) characteristics of the innovations; (3) channels through which the innovations are communicated; and (4) the social structures and norms of the society in which the innovation is being diffused.³³ According to Rogers, a sufficient amount of time is required for the farmers to decide whether to adopt or reject new technology as they try to learn more about the benefits, risks and uncertainties. In terms of adoption pace, potential users of technology can be categorized into one of five groups: innovators, early adopters, the early majority, the late majority, and laggards.³⁴ Four years—the length of time ATDC has been operating—is generally considered to be sufficient for technology adoption, yet thus far, no thorough analysis of the role of time in the ATDC case has been conducted. Rogers' second factor connects the main features of the technology to the characteristics of its potential adopters. In order to be adopted, technology must be compatible and easy to understand, and farmers must be able to experiment with its use.³⁵ As such, it is necessary for technology adoption programs to ensure ease of access. Improved access to technologies can either be in a physical form (through improved distribution chains), financial (because of improved affordability), or technical (via weakened intellectual property regimes). As described below, some components of the technology package promoted by the ATDC are physically inaccessible to farmers, while the adoption of others is constrained by their cost.³⁶ In the third factor for adoption under Rogers' theory, the ATDC's communication system is challenged by the level of its interactions with farmers, and the lack of Swahili language skills among

the Chinese experts. Finally, applying Rogers' fourth factor for adoption to the case of the ATDC reveals the social impediments to adoption of Chinese rice varieties and technologies, such as the need for farmers to balance their personal preferences regarding the taste of rice against the potential economic returns from the improved Chinese rice breed.³⁷ Although the rice variety introduced by the ATDC may allow farmers to be more productive, its different taste seems to negatively influence its adoption rates.

RICE FARMING IN DAKAWA

UNLIKE THE INTERIOR PARTS OF MOROGORO REGION, the village of Dakawa has both strategic and geographic advantages for rice production, including easy access to electricity and transportation infrastructure, as well as an irrigation system fed by the Wami-Ruvu river basin. Agriculture remains the exclusive means of income for 51 percent of Dakawa residents; a large proportion of the remaining population subsists off of a combination of agriculture and small business, pastoralism, and other rural activities.³⁸ A study conducted in 2014 affirmed that rice is the major crop in Dakawa, with cultivation occurring in both the village's cooperative irrigation scheme and the village's dryland. In the irrigation scheme, rice is often grown biennially, while the dryland allows only one season of rice cultivation per year.

The history of rice farming in Dakawa dates back in the 1981 when the village was selected for a partnership program between North Korea and Tanzania. This bilateral cooperation yielded a state-owned rice farm and a laboratory for joint rice research

activities, from which an improved breed known as "TXD-306" was developed. It was also during the Korean partnership that Dakawa was equipped with powered pumps to channel water from the Wami River into an open gravity-driven distribution canal. Under this joint scheme, 3,000 hectares were developed for irrigation, which transformed the village into one of the country's major rice irrigation zones.³⁹ The partnership lasted for a decade before it ended during the early 1990s.⁴⁰ Following the decline of the

bilateral cooperation, the paddy irrigation scheme landed under the management of the National Agriculture and Food Corporation (NAFCO), while the research facility was turned into a research station known as Cholima, managed by the ministry responsible for agriculture in Tanzania.⁴¹ The collapse of NAFCO in 1996 triggered privatization for most of the state farms, but the Dakawa paddy was abandoned for a decade before it was handed over to UWAWAKUDA. Subsequently, the UWAWAKUDA association restored an irrigable paddy of 2,000 hectares out of the total 3,000 hectares. The Cholima research station was also allocated 100 acres within the irrigated scheme, giving its management automatic membership to UWAWAKUDA.⁴²

The UWAWAKUDA irrigators' cooperative is composed of 840 members, each of them allocated with plots of 2 to 12 acres.⁴³ Some of the farmers in the irrigation scheme also reportedly grow rice in the dryland within the village. This study

Dakawa has a strategic and geographic advantage for rice production; agriculture is the primary source of income for 51 percent of the population.

discovered some differences between the two farming areas in terms of technological choices and levels of productivity. For example, unlike in the irrigated farmland, farming in the dryland involves freelance practices where farmers operate under no regulatory frameworks or enforced technological choices. Field observations and farmer interviews indicated that the dryland farming is based on the traditional rain-fed method with a predominant cultivation of indigenous breeds of rice, and the total yield per hectare is relatively lower than in the irrigated farmland. The irrigation scheme, on the other hand, has been shaped by the regulations set by the cooperative, which defines the rice breed to be cultivated and the cropping calendar, among other items. Other aspects of management including the membership fees, cost sharing for the operation of pumps, and canal maintenance are governed by the association's constitution.

THE CHINESE ATDC IN DAKAWA

NUMEROUS STUDIES HAVE OFFERED INSIGHT into Chinese ATDCs across Africa, including their historical evolution, their construction activities, and their early stages of operation.⁴⁴ However, few, if any, studies thus far have included empirical evidence on ATDCs' contribution to the improvement of agricultural production and productivity among targeted African farmers. Nevertheless, according to the Chinese Ministry of Commerce's website, the aim of ATDCs is to promote mutual learning and the exchange of expertise between China and Africa. ATDCs allow Chinese experts to share their experiences while improving China's understanding of Africa's agricultural needs. At the same time they aim to improve the productive capacity of Africa:

Taking stock of the previous work of agricultural technology demonstration centers, the Chinese government will plan and implement in the next three years a number of new agricultural technology demonstration center projects, so as to further strengthen technology training and demonstration with a focus on improving grain production, processing, storage, transportation and marketing capacity of African countries.⁴⁵

The core mission of the Chinese ATDC in Dakawa is to provide demonstrations of improved cultivars and techniques, and to train local farmers and technicians about Chinese agricultural technologies, particularly rice. The ATDC in Dakawa focuses on rice, with variety trials and demonstrations of the ten different hybrid rice cultivars from the Chongqing Academy of Agricultural Sciences, through its subsidiary Chongqing Zhongyi Seed Co. Ltd.⁴⁶ The ATDC packages the hybrid rice varieties with improved farming techniques, which have been designated, tested, and proven to yield high levels of success at the province of Chongqing in China, where they are standard practice.⁴⁷ In addition to the breeds and farming techniques, the Dakawa ATDC has also attempted to promote some agro-mechanization tools from China. The center is equipped with a modern tissue culture lab; imported power tools including tractors, harrows, plows and rice harvesters; and some non-power basic tools. The primary

mode of promoting the mechanization tools is by using them in the training and demonstration activities, to stimulate the interests of farmers to purchase similar products in the future.

Most of the training courses have been designed to be taught in a single day. The majority of trainees are the farmers from Dakawa and neighboring villages. A typical full day training at the ATDC begins with a presentation of up to three hours in the morning, followed by a tour of the center. In the afternoon, trainees have the opportunity to get some hands-on experience in the field. The multimedia-enriched presentation is normally delivered in English with a Swahili translation to accommodate the majority of trainees. Towards the end of the training day, trainees are guided by Chinese experts to practice some of the newly-taught skills. Depending on the season, these may include transplanting rice in the demonstration field from the seedling nursery, paddy field preparation, or modern harvesting techniques. In general, the training program was found to cover a broad set of skills related to sowing and paddy preparation, leveling and water lodging prevention, nursery care, transplanting techniques, management of the soil nutrients, and input application.

Farmers may receive special invitations to observe the farming activities and outputs from the Chinese technology at the ATDC. For example, extension officers in Dakawa and neighboring villages may nominate people, particularly farmers, for

invitations to the annual farmers' day celebration during the rice harvesting season. About 300 visitors who attend this event annually witness the harvesting process and the yield from Chinese hybrid rice. Visitors receive portions of the harvested rice and maize as a gift to taste, as well as some basic farming tools such as handheld pesticide sprayers. The demonstration center also offers open access to farmers and other interested visitors, allowing them to enter at their own convenience. Usually visitors must first speak to the security guard, who relays the message to the Chinese researchers. Depending on availability of the Chinese experts, visitors may be offered a short guided tour around the demonstration farmyard and the poultry facility. This is easier if the visitor speaks English. The Chinese researchers and technicians at the ATDC have also been engaged in an outreach

program. This includes regular visits to farmers, and it allows the Chinese researchers to provide some field extension services. Outside of Dakawa and neighboring villages such as Msufini, Mvumi, and Hembeti, the center has also established linkages with rural development projects, including the Peapea Village Community Development Scheme, and a rice farming scheme in the Rufiji area. According to officials at the ATDC, over 500 consultation visits have been made to facilitate understanding of the challenges faced by local farmers.

Apart from the training and demonstration services offered, the ATDC is also a vehicle for China to exert soft power and influence, and to safeguard the commercial interests of the Chongqing Agricultural Academy. The ATDC's popularity, which is reinforced by its advantageous location, has spurred many local and international

The core mission of the Chinese ATDC in Dakawa is to provide demonstrations of improved cultivars and techniques, and to train local farmers and technicians about Chinese agricultural technologies, particularly rice.

visitors, including researchers, national and local government leaders, and diplomats. China's influence is bolstered by the uniquely high performance of the prestigious 'Q You' hybrid rice from the Chongqing Academy, which yielded an average of 12 tons/ha after a series of trials in Dakawa, Katrin, Rufiji, and Mombo sites.⁴⁸ The Chinese farming techniques alone are said to result in a 20 to 30 percent improvement in productivity for the local rice varieties compared to traditional methods. The yield performance of the Chinese hybrid rice and the state-of-the-art laboratories and facilities are used to showcase the achievements made by China in agricultural development, and to portray an image of China as a successful and powerful economy. Moreover, the ATDC has captured the attention of the media and political figures. After the center's grand opening ceremony, which was officiated by the President of Tanzania, several other state visits have been reported, including ones by the prime minister and by various ministers of agriculture.

Under the bilateral agreement, the Chongqing Company is expected to attain financial sustainability after three years of funding from the Chinese government. The company's efforts to break even led to its engagement in non-rice activities including horticulture and egg-laying projects, for which the products are being sold in Dakawa and in neighboring towns. The community of Chinese men in the Morogoro and Dodoma regions, including construction workers, are the major buyers of vegetables and other products of the center. During the second field visit in 2015, observations showed that the horticulture project had extended into the unfenced 50 hectares farmland. However, the manager of the ATDC that was interviewed insisted that the business was still unprofitable even with the expanded cultivation into this area. Several constraints, including the costly irrigation system, might have impacted the ATDC's ability to operate commercially.

ANALYSIS

THE ATDC'S ROLE IN DIFFUSING AND TRANSFERRING Chinese agro-technologies in Dakawa can be examined through two lenses: first, by assessing the milestones towards the realization of the center's goal of disseminating the improved rice farming technology, and second, by investigating the center's influence on the pace of farmers' adoption for improved rice technologies.

PROGRESS TOWARD MEETING THE ATDC'S GOAL

NO REFERENCES TO SPECIFIC PERFORMANCE TARGETS for the ATDC were made in the bilateral agreements or the interviews with Chinese officials. The ATDC's manager denounced the Western style of monitoring and evaluation, such as the preparation of regular reports and performance indicators. He instead emphasized the center's broad goal of empowering local farmers through training and the demonstration of improved Chinese technologies. There have been great strides towards achieving this

goal, with over 900 farmers having benefited from the ATDC's training courses between 2011 and 2014.⁴⁹

The ATDC has an open door policy for students who intend to pursue their internships in the field of agriculture. Based on this policy, 60 undergraduate students from different agricultural training institutions in Tanzania had interned at the center by the end of 2015. Furthermore, the center hosted Tanzanian researchers, including two Ph.D. researchers and two postdoctoral researchers. The postdoctoral researchers had no supervisory or collaborative linkages with Chinese experts at the center. The researchers conducted their own experiments on tissue culture and the breeding of local rice varieties as a point of comparison with Chinese hybrid rice.

Nevertheless, the ATDC's manager, Professor Chen Hualin, was not very excited about his center's outputs, given its capacity and potential. The center is equipped with spacious classrooms, dining halls, and dormitories to host dozens of trainees for multiple-day training courses. The center's performance could benefit a great deal from improved external linkages with other related rice sector interventions, particularly those located in Dakawa. Our analysis found that, by the end of 2015, only the Korea International Cooperation Agency had utilized the ATDC's state of the art facilities to train local farmers. During a follow-up interview, Professor Hualin felt that the number of trainees could increase significantly through stronger collaboration with local institutions. Since the Chinese government subsidy does not cover certain costs such as travel and living allowances, the ATDC is compelled to rely on other resources, such as from the local government authorities (LGAs) and other collaborators. Such co-financing modalities are necessary for improving the reach of the program, for example by supporting longer training durations with financing to provide boarding trainees for multiple days. Hualin is also convinced that, unlike the current situation where the trainees are predominantly farmers, a co-financing arrangement would allow his center to expand the reach of its public agricultural services countrywide. Key government officials who visited the ATDC have reportedly expressed interest in sending farmers from their areas to attend the ATDC, but these goals have not yet been realized.

A number of structural barriers have impeded the ATDC's ability to effectively diffuse rice farming technologies in Dakawa. Some barriers result from limitations on the Chinese side, while others stem from the nature of the Tanzanian government's support for the center. On the Chinese side, researchers at the ATDC have demonstrated poor engagement with key stakeholders in the rice sector in Dakawa. For example, respondents acknowledged the lack of formal links between the center and local institutions including URAWAKUDA and the village government of Dakawa. Such linkages are important for facilitating the interactions with farmers and enhancing the center's overall performance. Moreover, ATDC's operational model acts as a barrier to technology diffusion. The center seeks to import and disseminate a package of rice farming technology from China in order to stimulate demand in the Tanzanian market. The Q-You and other Chinese rice varieties are patented by the Chongqing Zhongyi Seed Company. As a result, farmers have to depend on the company for the

supply of seeds, which prevents collaborative research and development (R&D) and improvements in response to the local demands. At the Cholima research station, the collaboration with ATDC is seen as weak as it lacks joint research activities, unlike the North Korean partnership which involved a combination of ideas, technologies and research efforts between the two partner countries.

On the Tanzanian side, the bilateral agreement for the Dakawa ATDC was signed between the Chinese Ministry of Commerce (MOFCOM) and the Tanzanian Ministry of Foreign Affairs, and thereafter the management was transferred to MAFC. The ATDC's manager reflected on the MAFC, noting that it is a good collaborator and facilitator on key operational requirements. The MAFC offers numerous services, including the processing of work permits, tax exemptions, and customs clearance for imports. Nevertheless, there are significant shortcomings with respect to the overall assessment on fulfilment of Tanzania's commitments, which was viewed by three respondents as an outcome of the MAFC's limited ownership. Examining the two major contractual obligations reveals a number of shortcomings. For instance, the pledge to power the site was only accomplished about eight weeks after launch, following the directive from President Kikwete. In another example, the commitment to construct an irrigation system to connect the ATDC with the Wami River was not completed by the end of 2015. As a result, the ATDC was compelled to pursue costly investments to feed the demonstration field, such as the construction of a deep borehole and subsequent pumping of water from underground. Generally, the infrastructure-related increase in operational costs hampered the ATDC from attaining financial sustainability, and from improving its reach to beneficiary farmers.

In addition, the inability to license Q You and other Chinese hybrid rice varieties has constituted a major structural barrier to technology diffusion at the ATDC. By the end of 2015, the ATDC had not secured a license for hybrid rice to be commercially distributed to Tanzanian farmers. Chinese experts saw local bureaucracies as the main source of the delay, while the MAFC officials pointed to the lack of patience and the failure to comply with local regulations on the Chinese side. Because of the ATDC's inability to secure a license for the hybrid seed, we were unable to examine the overall technology diffusion for the hybrid rice.

ATDC'S IMPACT ON ADOPTION OF IMPROVED RICE FARMING TECHNOLOGY AMONG DAKAWA FARMERS

ASIDE FROM THE HYBRID SEED, the farmers' adoption rate of new technologies has diverged from the ATDC's reported performance. As discussed previously, the diffusion process depends on various factors including time, accessibility to the technology, characteristics of the target technology that may either encourage or discourage its adoption, and characteristics of farmers which may influence their decision to adopt. Most of the farmers interviewed were aware of the ATDC's presence in their village, but few understood that the ATDC's principle aim was to spread knowledge and technology about rice farming. Conversely, local farmers saw the center as a place to

Table 1: Farmers' awareness of and interactions with the ATDC

Question	Yes	No
Aware of the Chinese ATDC's presence in Dakawa (n=39)	39	0
Aware of training and demonstration services of the ATDC (n=39)	27	12
Aware of other services of the ATDC (e.g., selling eggs) (n=39)	32	7
Has visited the ATDC for training/demo at least once (n=23)	12	11
Has been visited by Chinese researchers on his/her farm (n=23)	1	22

* The smaller N in the last two rows is the result of methodological weakness during two early focus groups regarding the disaggregation of group to individual-level responses..

buy eggs and vegetables at a cheaper price.

Table 1 summarizes farmers' perceptions of the ATDC and their reported entry to the ATDC for training and demonstration related activities. About half of the respondents benefited from the demonstration and training services offered within the ATDC facilities. Three of the respondent farmers indicated that they had been invited as many as four times to visit the center between the ATDC's launch in 2011 and 2015, while others reported that they were not given similar opportunities. The visits to the center were mainly to participate in the training programs and to celebrate the "farmers' day" during the harvesting season. Five farmers had not entered the ATDC for training or demonstration purposes, but rather to purchase poultry products and vegetables. Only one respondent farmer indicated that she was visited on her farm by a Chinese expert as part of the ATDC's extension program.⁵⁰

Farmers diverged in their opinion about accessibility of the ATDC, with some respondents seeing the compound's gate house as a barrier, while others felt that the center was easily reachable:

Most of us (Dakawa farmers) are scared of visiting the place because it is fenced with a gate. But from my experience, it is very easy to enter and request of a tour around the whole compound and learn what they are doing there. I could see and learn many things, although I did not understand everything the Chinese man said. I have applied the skills from there to my rice farm and also for growing maize and vegetables.⁵¹

As a result of the aforementioned structural inaccessibility of Chinese rice breed and limited affordability of the Chinese mechanization equipment, this assessment of the success of technology diffusion is focused on the Chinese rice farming techniques, focusing on four techniques in particular: field preparation techniques (including leveling and the construction of bunds), nursery and transplanting techniques, fertilizer application, and the management of the soil nutrients. For each, we examine the ATDC's influence on improving awareness about the technique, promoting the benefits of using the technique, and stimulating the application of the technique.

Patterns of adoption for each technique were examined through a combination of field observations and in-depth interviews with farmers.

The study found that all 39 respondent farmers gained a basic level of awareness about the four techniques, and they attributed their awareness to a broad range of information channels. Farmers acquired knowledge through both theoretical and practical methods, including training, demonstration, and information materials distributed by governmental and non-governmental actors over the past decade. The importance of the ATDC in disseminating information and knowledge varied widely. Only 7 of the 39 respondents cited the ATDC as an exclusive source of information on one or more techniques. Five other respondents commended on the strong influence of the ATDC, but acknowledged that it was not their only source of information. The box on page 17 details the role of the ATDC in influencing the adoption rate of one particular transplantation technique.

Farmers did not engage in techniques which were deemed important, but which demanded intensive capital and advanced mechanization tools.

During the focus groups, farmers reported yield performance as the most important factor influencing their confidence in the ATDC. For example, ten farmers had reportedly never seen rice husks, maize cobs, or pumpkins as large as those found at the Chinese facility. These ten farmers also exhibited high levels of excitement with respect to the yield of 7 tons/ha from TXD 306 at the ATDC facility, which had yielded only 4 tons/ha at their farms. Such experiences seem to have positively impact farmers' perceptions about the benefits of investing in improved farming techniques. On the contrary, the remaining 29 respondents were suspicious of the ATDC's productivity, maintaining that it was "too good to be true." During the focus groups, the farmers debated issues ranging from the importance of the Chinese people's work ethic to the governmental subsidies that may have made it impossible for local farmers to replicate the ATDC's yield performance on their own.

During the focus groups respondent farmers favored the Farmers' Field Schools (FFS) approach, which is advocated by the NAFAKA project. In this system, a set of randomly selected volunteer farmers are trained and equipped with improved technologies to apply in their field and to train their peers. This approach appealed more to farmers than the ATDC's demonstrations and associated high yield, which were seen as less practical for farmers day-to-day realities. Farmers indicated that the ATDC's performance was influenced by its intensive capital and foreign practices. An expert at the Cholima research station shared a similar opinion, acknowledging that the ATDC sees high productivity under the local geo-ecological conditions, but with limited consideration of and adjustment for the agronomical and socio-cultural factors local rice farmers face.⁵²

Variations in the rate of adoption of the four farming techniques were also observed among farmers. While some of the field preparation techniques such as tilling and bund construction did not vary significantly, some costly preparation techniques such as field leveling were avoided by farmers. Farmers did not engage in techniques which were deemed important, but which demanded intensive capital and

Box 1: Adoption of rice transplanting technique

Rice is planted either by sowing seeds directly into the field—often through a method called “broadcasting”—or by growing the seeds in a seedbed before transplanting the seedlings into the field. Transplanting requires more labor, but it is also less demanding for irrigation, requires less weeding, and consumes fewer seeds, all while also offering higher yields. The technique has been proven to have more benefits and better results than the traditional broadcasting methods, although not all farmers are aware of this fact.

Respondent farmers were generally aware of both methods, although they did not all understand and appreciate the advantages and disadvantages of each. Some respondents found transplanting more costly, especially in the non-irrigated land, while others were fully convinced that it costs less, and leads into higher yield and better income. At least seven service providers were cited as sources of information on the benefits of this practice, and the ATDC was just one among these sources. While the ATDC seemed to have the strongest influence over the farmers’ decision to adopt transplanting, it is still difficult to completely attribute the farmers’ specific skills to the center, since the technique has been promoted by multiple agencies in Dakawa.

Most of the tools promoted for transplanting were handheld instead of advanced power machines. Yet, the limited access to these tools, the poor skills of farmers, and low capital influenced the slow adoption of the transplanting technique. Because transplanting requires more labor, farmers must balance their willingness to invest in transplanting against their capacity to implement the technique correctly. The ATDC’s efforts to raise awareness and build capacity is an important step towards promoting adoption. But awareness alone is not enough if other barriers such as finances and socio-cultural ties to traditional practices are not also addressed. According to a similar study by Nakano & Kajisa, financial instruments including microfinance services would stimulate the adoption pace for such improved tools and techniques.

In Dakawa, farmers tend to apply transplanting and broadcasting practices in their irrigated and non-irrigated farms, respectively. The UWAWAKUDA cooperative enforces the use of modern technologies including the application of the improved TXD 306 seed and transplanting techniques. UWAWAKUDA’s regulations are backed with loan facilities from the association’s savings and credit society, and also the NAFAKA-facilitated access to external financiers. The loan packages enable the farmers to pay for the increased labor, inputs, and machine hiring costs demanded by improved techniques. As such, farmers tend to operate a dual system in which they practice transplanting with the improved variety in their irrigated paddy while maintaining the broadcasting method with traditional varieties in their non-irrigated farmland. The land-intensive

Farmers' hesitation to transition fully to an improved farming system is mainly a result of limited finances and real-world experience, as opposed to a lack of knowledge and awareness of expert opinion.

traditional farming practices are sustained in the unregulated rain-fed system, using aromatic indigenous rice varieties that are said to be more tolerant to fluctuations in water logging. Interviewed farmers were fully aware of the yield variations between the two systems, and yet they chose to maintain the dual system. Farmers emphasized that their hesitance to transition fully to the improved farming system is mainly a result of limited finances and real-world experience, as opposed to a lack of knowledge and awareness of expert opinion. A combination of training, regulation, improvement of access to finance, and improvement of the irrigation infrastructure would be the best way to ensure widespread adoption, but the ATDC lacks such a package.

advanced mechanization tools. This was seen with nine farmers who reported to have followed the ATDC's recommendation of improving their application of fertilizers, but not up to the levels recommended by the Chinese. One farmer acknowledged the benefits of improved use of fertilizer based on recommendations by Chinese experts, but admitted to not being able to fully implement the practice:

I understand that intensive application of fertilizers pays more, and I was truly impressed by the yield at the Chinese center, but unfortunately I cannot afford twenty bags of fertilizer in one season which will be needed in my two acre paddy according to their standards.⁵³

There were also differences in adoption patterns between the irrigated paddies under UWAWAKUDA and rain-fed rice farms in Dakawa, as observed among six farmers who operated on both farming systems, and as illustrated in the box above that examines adoption of transplanting techniques. Within the irrigated scheme, farmers tended to transplant the improved variety TXD 306, and they applied the mineral fertilizers at an intensive rate. In contrast, the traditional method involves a direct seeding of the rice in the field randomly (also known as broadcasting). In this method, farmers tended to use the indigenous rice varieties, with minimal application of agricultural inputs such as fertilizers, and relied on rain to feed their fields. Productivity with the improved system is reportedly double that of the traditional method. The regulations of UWAWAKUDA exerted a strong influence on investment in and adoption of costly improved techniques and inputs. Regulations and complimentary services from the NAFAKA project, such as microfinance and linkages with input suppliers, gives it an advantageous edge over the ATDC, which is limited to training and demonstration services. One reason for the ATDC's limited influence over the adoption of improved technologies among the respondent Dakawa farmers is its failure to address the farmers' limited access to finance and uncertainties in return.

With regards to the hybrid seeds, farmers were asked about their willingness to adopt them should the seeds become available in the future. Only two of the six farmers who responded to this inquiry indicated that they would adopt and invest in

the Chinese rice varieties. Respondents described the Chinese hybrid rice as less tasty, non-aromatic, and sticky compared to indigenous varieties. However, a follow-up question to those who claimed that the hybrid rice was not tasty, revealed that they had not tasted the Chinese rice themselves; instead, they had only heard about the taste from neighbors. Their lack of willingness to adopt the hybrid rice was partly due to stereotypes. To overcome the negative perceptions and low appreciation of the potential rise in profit from cropping the higher yield Chinese hybrid rice, the ATDC must improve the technology promotion strategy. Nevertheless, the study could not find a strategy in place for the ATDC to stimulate demand for its Q You and other hybrid rice varieties upon their anticipated licensing in the future.

CONCLUSION

THIS STUDY EXPLORED THE BARRIERS that have prevented Dakawa farmers from fully adopting the Chinese rice technologies. The primary challenges include limited financial capacity to invest in improved technologies; attachment to the indigenous technologies and traditional practices; and regulatory requirements for farmers to access imported technologies like hybrid rice. Farmers are also constrained by their limited access to knowledge and information about the benefits and application of the technology. Of these barriers, the ATDC has largely addressed the knowledge and information barrier through its training, demonstration and extension services. By showcasing the benefits of different techniques, the center has stimulated farmers' willingness to adopt, and through exposure to the farming practices at the ATDC, more farmers have applied improved techniques at different stages of the farming process. While the demonstration center sought to maintain its primary function of building farmers' capacity, it has also showed limited engagement with other actors in the field including microfinance institutions, local government authorities, and donor agencies. Improvements in this domain is likely to enhance the scale of the ATDC's performance with more beneficiaries, wider geographical coverage and a broader scope of services. ★

APPENDIX

List of interviews and focus groups

#	Respondent(s)	Affiliation	Date	Location
Interviewee #1	Dr. Nkuba Jackson	DRD, MAFC	April, 08, 2015	Dar es Salaam Tanzania
Interviewee #2	Mr. George Iranga	Manager, Cholima research station	April, 13, 2015	Dakawa, Tanzania
Interviewee #3	Prof. Chan Hualin	Manager, Dakawa ATDC	April, 14, 2015	Dakawa, Tanzania
Interviewee #4	Mr. Ndimubandi Mvukiye	Researcher, Cholima research station	April, 15, 2015	Dakawa, Tanzania
Focus group #1	6 farmers		April, 16, 2015	Dakawa, Tanzania
Focus group #2	5 farmers		April, 16, 2015	Dakawa, Tanzania
Interviewee #5	Ms. Matembo	Agricultural extension officer, Dakawa	April, 17, 2015	Dakawa, Tanzania
Focus group #3	5 farmers		April, 20, 2015	Dakawa, Tanzania
Interviewee #6	Ms. Rehema Makame	Dakawa farmer #1	April, 20, 2015	Dakawa, Tanzania
Interviewee #7		Dakawa farmer #2	April, 21, 2015	Dakawa, Tanzania
Interviewee #8	Ms. Tatu Musa	Dakawa farmer #3	April, 23, 2015	Dakawa, Tanzania
Interviewee #9	Mrs. Veronica Uri	Dakawa farmer #4	April, 23, 2015	Dakawa, Tanzania
Interviewee #10	Mr. T. Kakeme	Chairman, UWAWAKUDA	Nov. 18, 2015	Dakawa, Tanzania
Interviewee #11		Treasurer, UWAWAKUDA	Nov. 18, 2015	Dakawa, Tanzania
Interviewee #12	Mr. Phillbert	Officer, NAFAKA Project	Nov. 20, 2015	Morogoro, Tanzania
Interviewee #13	Prof. Chan Hualin	Manager, Dakawa ATDC	Nov. 30, 2015	Dakawa, Tanzania
Interviewee #14	Dr. Sophia Kashenge-Killenga	Manager, Cholima Research Station	Dec. 01, 2015	Dakawa, Tanzania
Interviewee #15		Ward Executive officer Dakawa	Dec. 01, 2015	Dakawa, Tanzania
Interviewee #16	Ms. Chuki Ramadhani	Dakawa farmer #5	Dec. 02, 2015	Dakawa, Tanzania
Focus group #4	5 Farmers		Dec. 02, 2015	Dakawa, Tanzania
Interviewee #17	Mr. Matola	Dakawa farmer #6	Dec. 03, 2015	Dakawa, Tanzania
Interviewee #18		Dakawa farmer and agro inputs trader #7	Dec. 03, 2015	Dakawa, Tanzania
Interviewee #19	Mr. Mangula	Dakawa farmer #8	Dec. 04, 2015	Dakawa, Tanzania

Focus group #5	6 farmers		Dec. 04, 2015	Dakawa, Tanzania
Interviewee #20	Mr. Haule	Dakawa farmer #9	Dec. 07, 2015	Dakawa, Tanzania
Interviewee #21	Ms. Neema Mgaza	Dakawa farmer #10	Dec. 07, 2015	Dakawa, Tanzania
Interviewee #22	Mr. Temi	Manager, Mkindo Training Center	Dec. 08, 2015	Mkindo, Tanzania
Interviewee #23	Mr. Rajabu Kihimbwa	Dakawa farmer #11	Dec. 10, 2015	Dakawa, Tanzania
Interviewee #24	A. Majuto	Dakawa farmer #12	Dec. 10, 2015	Dakawa, Tanzania
Interviewee #25	Chinese official	Chinese embassy Dar es salaam	Dec. 14, 2015	Dar es Salaam Tanzania
Interviewee #26	Dr. D. Nyange	Senior Advisor, USAID Tanzania	Dec. 15, 2015	Dar es Salaam Tanzania

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48. The yield is significantly above the average Chinese productivity of 6 tons/ha (according to the IRRI database), and the 7 ton/ha average from the local variety TXD 306 under similarly-improved farming techniques.
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52. Interviewee #4, Researcher, Cholima Research Station, Dakawa Tanzania, April 15, 2015.
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