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Review

A Review of Agricultural Technology Transfer in Africa: Lessons from Japan and China Case Projects in Tanzania and Kenya

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Abstract: Agricultural technology transfer plays a chief role in transforming agricultural productivity in rural areas especially in the current setting where food demand surpasses the production capacity. Technology transfer facilitates the movement of soft and hard skills essential for improving farm production. Yet, the technical cooperation projects in Africa have been suffering from effectiveness and sustainability challenges while lacking responsiveness to local demand. This study applies a system dynamic method and a literature review to bring lessons from Japan and China's experiences in agricultural technology transfer projects to Africa. Three cases in agricultural technical cooperation projects are presented: China—(Agricultural Technology Demonstration Center (ATDC) in Tanzania), Japan—(Smallholder Horticulture Empowerment Project (SHEP), and Rice Industry Development Support (RIDS) in Kenya and Tanzania, respectively). Japanese and Chinese agricultural technology has the potential to improve productivity and the livelihood of rural households. Nevertheless, strong linkages, commitment, and participation of all stakeholders in the design and implementation of agricultural technology transfer projects play an important role in enhancing project sustainability in the recipient countries. Further studies are recommended such as, to explain the agricultural technology transfer mechanism that fits well to equip beneficiary autonomy in terms of knowledge and capacity of production in the recipient country. The local governments need to set policy environments and institutional frameworks that encourage and support the agricultural technology transfer to benefit the rural farmers.

Keywords: project challenges; technology transfer; technical cooperation; sustainability; effectiveness; China–Africa; Japan–Africa

1. Introduction

Agriculture remains important in Africa [1,2]. However, inadequate assimilation of technology is limiting the rate of agricultural growth over time, and thus affect both quantity and quality of what is produced. In line, the food demand in Africa keeps increasing behind production capacity, suggesting the needs for technical upscaling to improve farm yield [3–5]. While African agriculture is still characterized by inadequate skills, research, innovation, and technology, the farming yields are said to depend greatly on applied farming technologies such as machinery, genetically modified organisms, and fertilizers [6,7]. Yet, the arrival of new technologies are often met with resistance by agricultural producers as the agricultural knowledge system is built on long-standing cognitive, social, and institutional processes which are not easy to change [7]. Various stakeholders such as extensions, research organizations, and development partners continue to play innovative roles in transferring new technology to agricultural producers but the change is very slow, limited, and incomplete [8].

However, there is a high volume of literature on the impact of foreign technical aid on development in Africa, yet it does not recognize all factors that contribute to technical aid (in) effectiveness. As a result, technical aid projects to transfer foreign agricultural technology are still suffering from lack of sustainability, and its impacts to farmers is not very clear over time [9,10]. Literature suggests that the proportion of agricultural aids to Africa is declining, yet the need for assistance is still high [11,12]. Even after years of experience in agricultural technology transfer, most donors today, remain confused on how to package, coordinate, and deliver technical aid to impact agricultural and rural development in Africa [13]. Although some technical assistance seems to have been successful in building institutional and technical capacity, such examples appear more the exception than the rule [14].

The deployment of agricultural technology in Africa, is still lagging far behind, relative to developing countries in North America and Asia [15]. For this course, the efforts to support Africa to catch up deserve considerable attention among international communities [10,16]. Japan and China are among development partners in Africa where their path of economic development experienced traditional agriculture such as African countries. Therefore, it is believed that Japan and China have accumulated enough experience and technical know-how that may fit sharing with African friends during the process of agricultural transformation.

For decades, the African economy has relied on the agriculture sector regardless of the low level of crop productivity [6,17–19]. The continent is characterized by smallholder farmers who constitute about 80% of all farms in the region [20], but practicing subsistence farming because of low technology [21]. In this case, such farmers produce firstly to feed their households, and if any surplus for sale. As long as productivity remains low across a variety of measures, Sub-Saharan Africa continues to suffer from poverty and food insecurity while the spread of agricultural techniques such as improved seeds, efficient utilization of fertilizers, and pesticides is not promising [4,5,22,23]. For instance, according to production data of Africa, Japan, and China from USDA foreign agriculture services in 1960–2018, the African region has not made tremendous rice yield improvement when compared to China or Japan. In fact, Figure 1 reveals that the rice yield trend in China was more relatively closer to Africa in the 1960s than Japan in the 2000s. It is obvious that China has made remarkable progress over time while Africa remained behind. Literature has revealed that, Chinese agriculture underwent the technical change over time whereby farmers who had relied on high labor inputs to raise land yields per unit, began to change their inputs structure, by significantly reducing the labor input and increasing machinery and capital investment in agricultural production [24]. In line with the Asia green revolution, Chinese success in agricultural transformation provides inspiration and experiences of what technology transfer may do to African countries as well. In contrast, African traditional agricultural practices should necessarily be replaced by appropriate technology practices, which may offer a great avenue for farmers to shift from poor to high yield and farming practices. As a matter of fact, the agricultural improvement is of importance because an increase of agricultural productivity is the powerful catalyst for poverty reduction in rural areas of Africa, and its impact is almost three times more than the growth in manufacturing [25,26].

Comparative studies between Asia and Africa have projected Africa to rely on technology change and innovation in agricultural transformation [27,28]. Similar to Asia, the momentum of Asia green revolution initiated by agricultural technology transfer from the temperate zone to tropical zone countries [29], although such replication efforts have earned minimal effects in African agricultural growth if compared to Asia region [13,30]. On the other hand, the failure of technical aids and cooperation projects to earn sustainable results has posed a question on how to package, coordinate, and deliver technical aid to impact agricultural and rural development in Africa? [9,11–13,30]. While understanding the experiences and mechanisms may enhance aids effectiveness and impact of technology transfer projects in Africa, it is worthwhile learning through the experience of Japan and China operations in agricultural technical cooperation projects in Africa. Considering the fact that, financial support and technical know-how are provided during the agricultural technical cooperation projects in rural communities.

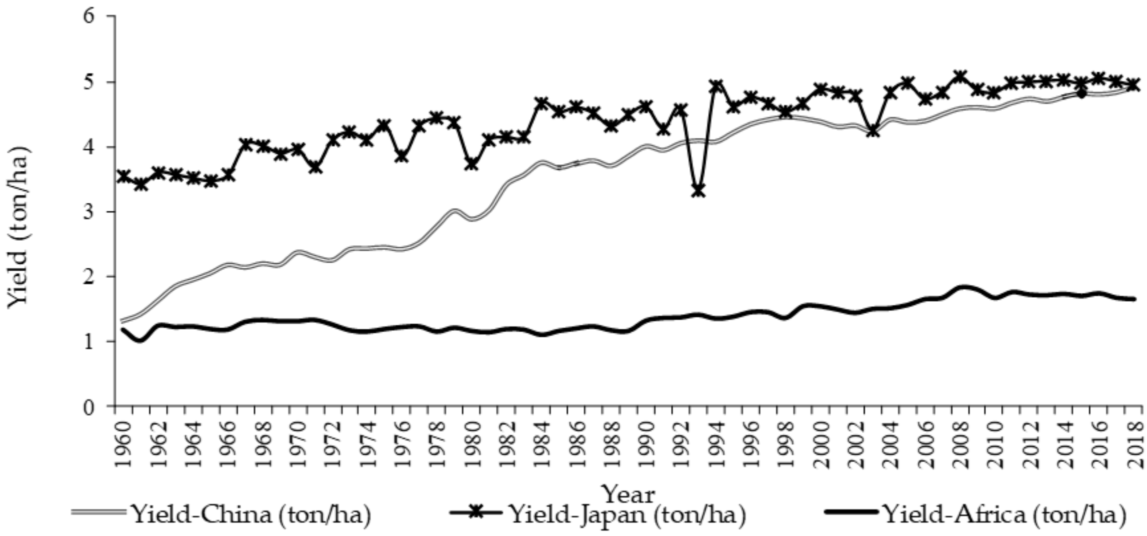

Figure 1. Rice yield trend in Africa, Japan, and China: (Milled equivalent: 1960–2018). Source: USDA PS&D Online data from http://worldfood.apionet.or.jp/index-e.htm.

From the early 1960s, Japan and China began the journey of technical cooperation with African countries in the form of bilateral cooperation. Though, in recent years, China has shown increasing interest to support African agricultural development via China–Africa agricultural cooperation. Considerable progress is noted in exchanges and training on agricultural technology, and agricultural technology demonstration centers project [10]. Notwithstanding, while some agricultural projects are being successful in Africa, many are reported to lack responsiveness to local demand and the effect is not ideal [9,10,31]. It implies that the sustainable benefits of technical cooperation projects are yet to be traced after several years of the technical project period. Thus, effectiveness and sustainability operations are challenging problems that need to be addressed in technical cooperation projects to enhance the impact of agricultural technology on-farm yield, food, and income after the project period. Sustainability of a project ensures that the benefits from a project remain for extended periods of time that can justify the economic and social input invested into the technical cooperation project [32]. However, following Agola [33], the ineffectiveness of agricultural technical aids may be resulting from mismanagement of the continuous process of technology transfer. The operation mechanism of technical projects in the recipient country, institutional surroundings, and the level of inclusive participation of beneficiaries also decide the effect of technology transfer, effectiveness, and sustainability of agricultural technology. Instead, efforts by the recipient side to assimilate the technical know-how through the long learning process, implementation, and innovation to suit the local demand environment have the potential to ensure the impacts and sustainability of technical cooperation projects. This motivates us to identify the key success factors of the sustainability of agricultural technology transfer projects, by considering China and Japan case projects of agricultural technical assistance in Africa.

2. Methodology

We apply a system dynamic method which acknowledges that any project operation is a system in nature, in which different parts interact to achieve a collective goal. The system dynamic employed to present the *dynamic complex nature* and interacting factors for enhancing the sustainability of technical cooperation projects benefits. A system dynamic set a conceptual tool that enables us to understand the structure and dynamics of complex systems [34], and therefore provides decision-makers with a lens to frame the processes affecting the sustainability of technical project impacts, and to set robust policies in the long run [35]. According to Rumeser and Emsley [36], the characteristic of agricultural technical projects may fit the nature of the system because such projects exist in a specific environment to achieve specific objectives, and have internal parts such as resources and deliverables, which are characterized by interrelationship. On the other hand, similar to systems, projects consist of inputs and outputs where inputs are project resources (e.g., agricultural technology) and outputs are project deliverables (e.g., an increase of yield per acre and farm income). According to [37], a *dynamic complexity* is found in situations where cause and effect are subtle, and where the effects over time of interventions are not obvious. This is true to agricultural technical cooperation projects in Africa, where regardless of many interventions since the 1960s, the level of crop productivity is not ideal over time. The system dynamics approach enables us to study the dynamic systems which change over time and finding the 'why' (cause) and 'how' (pattern) of system changes [38]. The authors of Uriona and Grobbelaar [39] presented three main ways to represent system dynamic models: (1) Causal loop diagrams (CLD), which offer a qualitative understanding of the system in study, highlighting its feedback structure; (2) stock and flow diagrams (SFD), which serve to understand the dynamic behavior of the system, through computer simulations; and (3) the mathematical notation under the SFD, which are differential equations. The current study only applies the first model (CLD) to create *cause* and *effects* diagram to analyse the system. The *causes* are the factors/variables that contribute to *effects* (i.e., the sustainability of benefits/impact in agricultural technical cooperation projects) over time. To create a CLD, one needs to identify the variables associated with a system, identify which of these variables are causally related to other variables within the system, and then decide whether the effect of one variable on another is positive or negative [40].

We began by focusing on China and Japan technical agricultural projects in Africa to illustrate the role played by donors in the process of agricultural transformation. Then, we presented the case projects to demonstrate the opportunities and challenges in the sustainability of technical transfer project operations. Along with three cases of projects in Kenya and Tanzania (ATDC, SHEP, RIDS), we reviewed the literature on African agricultural cooperation and technology transfer projects with Japan and China, and then, argue for factors for the sustainability of agricultural technical projects benefits. We finally, use CLD to figure the interactions of the factors in system dynamic nature and discuss what this means for agricultural technical projects. The selection of case projects was based on previous studies, reports, records, and documentaries. ATDC represent the main agricultural technical project designed to transfer technology between China and Africa by means of research, demonstration in farms, extension, and training [10,31,41–43]. The ATDC is also regarded as the flagship program to extend technology transfer in China–Africa cooperation, whereby the primal objective is to improve food security [31,43]. The SHEP and RIDS are among the successful Japanese agricultural technical cooperation projects in Africa [44–48]. While RIDS addresses the technical transfer in rice production for improving food and income, SHEP is set to address agribusiness challenges [44,49–51]. More details of these cases are presented in Sections 3 and 4.

3. Background of China and Japan Participation in Agricultural Technology Transfer in Africa

China and Japan's agricultural support began to expand from the 1970s, to help African countries achieve self-reliance and solve food insecurity problems [31,52,53]. Both have engaged in various agricultural cooperation projects to improve farm productivity and profitability by enhancing local technology. In recent years, China and Japan have used Forum on China–Africa Cooperation (FOCAC) and Tokyo International Conference on African Development (TICAD), respectively to address agricultural investment priorities and commitments for aid assistance to Africa. For instance, in the second FOCAC conference, the Chinese government announced investments through the Addis Ababa Action Plan (2004–2006) to support agricultural infrastructure, food security, and agricultural manufacturing sectors, and pledged to help Chinese companies that are willing to undertake agricultural development projects in cooperation with African governments [10]. Japan and China believe that a country's development depends mainly on its own efforts [52,54]. Therefore, technical cooperation projects are meant to support the production sector in fostering personnel and technical capacities underpinning the future development of local people toward self-reliance and independent development. Figures 2 and 3 present China and Japan agricultural aid to African countries in 2000–2013 where the sectoral aid data includes summation of agriculture, forestry, and fisheries industries altogether.

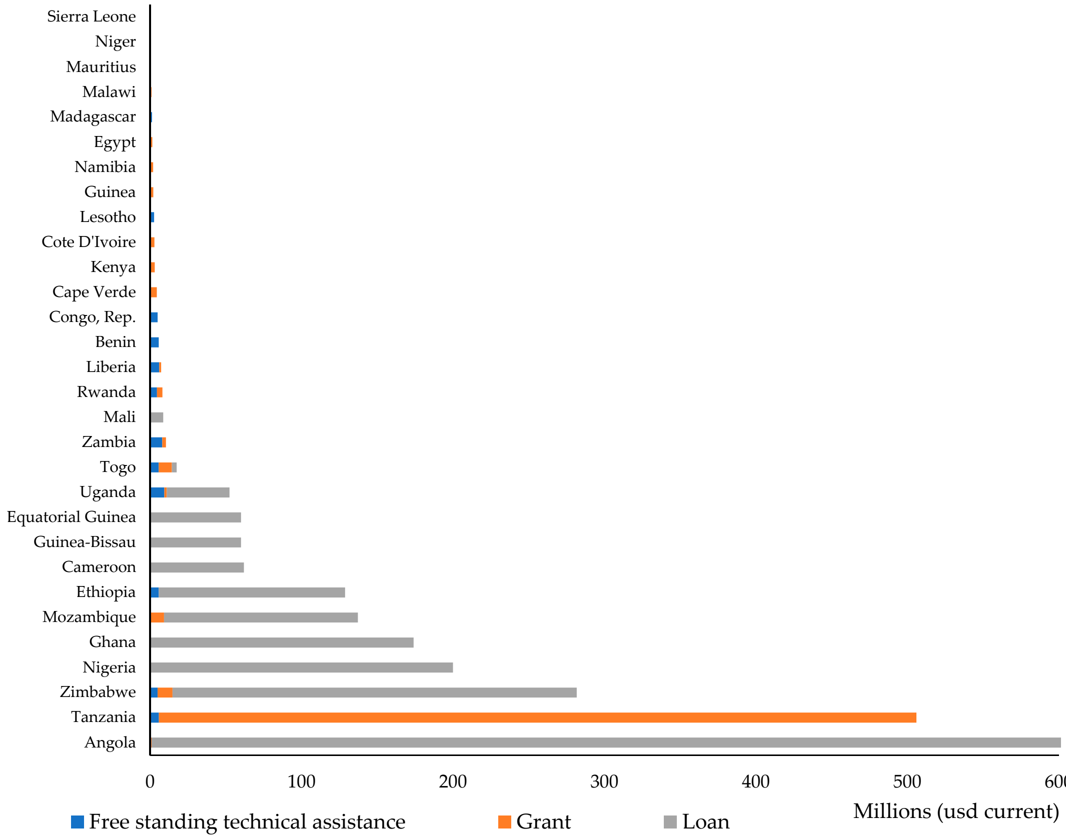

Figure 2. China agricultural technical aid to African countries in 2000–2013. Source: Aid Data's Chinese Official Finance to Africa Dataset, version 1.1.1.

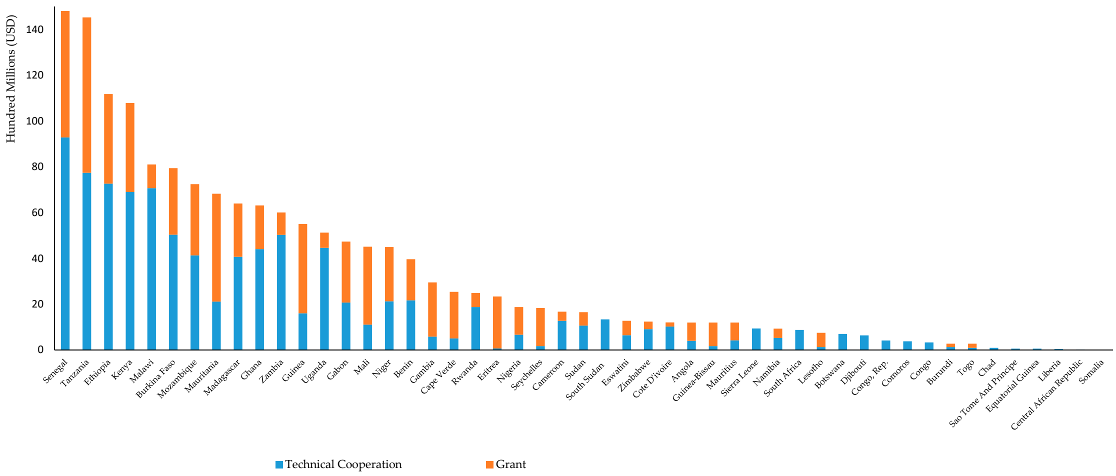

Figure 3. Japan agricultural technical aid to African countries in 2000–2013. Source: Japanese International Cooperation agency (JICA).

Japanese and Chinese agricultural cooperation contributes to agricultural development by improving local technology, institutional frameworks, and organizations. The technical cooperation with Japan gives emphasis on the development of human resources and strengthen organizational capacity through sharing technical equipment, know-how, and experiences [55]. China also presses the importance of human capacity development by dispatching experts and volunteers to the field or sending local people to China for training. The dispatch of experts/volunteers to Africa, or accepting the training in Japan/China is the main approach used in agricultural technology transfer projects which rely on the technical know-how and experiences embodied in experts. For instance, Figure 4 shows the number of participants in Japanese agricultural technical programs in Africa in 2000–2017. Likewise, between 2006 and 2017, China's Ministry of Agriculture has held 260 training sessions in China and trained 4980 agricultural officials and technicians from 54 African countries while about 950 experts and technicians were assigned to work in African countries [10]. Figure 5 shows the number of experts and technicians dispatched in African countries by South–South agricultural cooperation in 2011–2017.

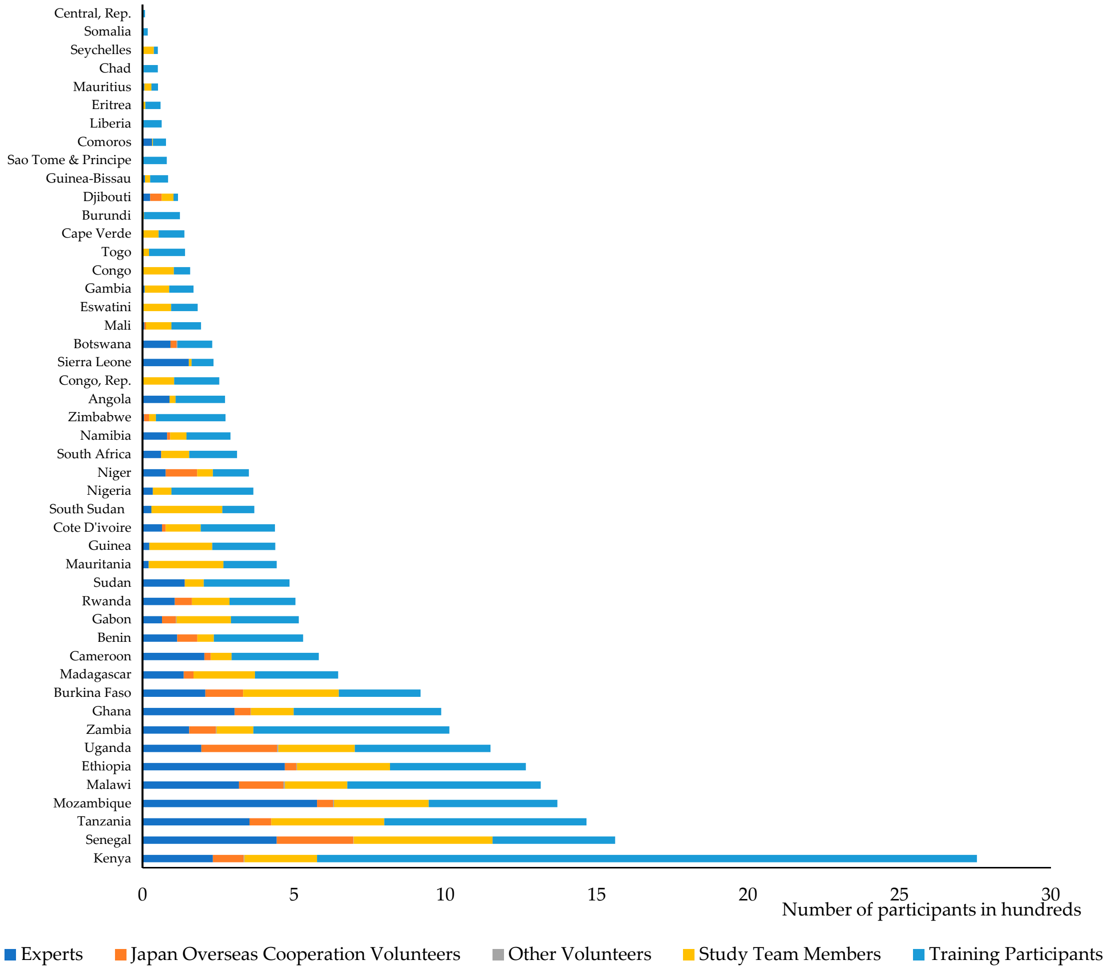

Figure 4. Geographical distribution of Japan agricultural technical cooperation to African countries in 2000–2017. Source: Japan International Cooperation Agency online database.

In 2006, China announced the opening of the Chinese market from Africa's agricultural products, the dispatch of 100 agriculture professionals and 300 volunteers for technical support, and Agricultural Technology and Development Center (ATDC) announced as a flagship program to extend technology transfer in China–Africa cooperation [31,43]. Likewise, China expressed the willingness and commitment to work with Africa in formulating and implementing a program of action to promote China–Africa cooperation on agricultural modernization and industrial promotion initiatives [56]. Under the framework of FOCAC, the Chinese government has sent 104 senior agricultural experts, and more than 50 agricultural technology groups, and established about 24 ATDC in Africa. China uses ATDC to facilitate indoor farmers' training and on-field demonstrations in the recipient countries. The ATDCs are constructed to demonstrate Chinese on-farm technology including agro-equipment, hybrid varieties, and agronomic practices [31,42].

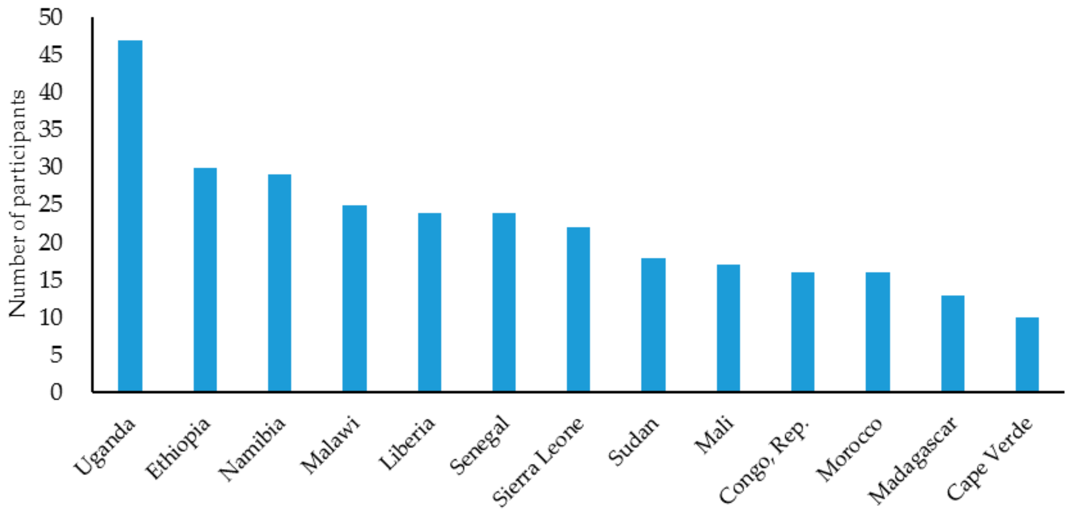

Figure 5. Experts and technicians dispatched in South–South Agricultural Cooperation project to African countries in 2011–2017. Source: China-FAO Trust Fund for South–South Cooperation, China Ministry of Agriculture.

In recent years, Japan committed to doubling the share of rice production in sub-Saharan Africa under the Coalition for Africa Rice Development (CARD) initiatives. The CARD is a consultative group of major donors, rice research organizations, and other development entities, which together are working with 23 African countries to strengthen the rice industry. The CARD was established by joint efforts of the JICA and Green Revolution in Africa (AGRA) and launched during the fourth Tokyo International Conference for African Development (TICAD IV) in 2008 [57]. The CARD is promoting the entire rice value chain approach through technical, financial cooperation, and research activities. Japan gives emphasis on improving the local rice cultivation techniques, irrigation, and water management systems and facilitating the post-harvest processing and distribution. The achievement of Japan's collaboration in Sub-Saharan Africa is believed to have contributed to doubling rice production [58]. Moreover, Japan uses agribusiness projects such as One Village One Product (OVOP) and Smallholder Horticulture Empowerment Project (SHEP) to educate farmers to change from the traditional approach of "grow and sell" to market-focused approach of "grow to sell". The SHEP has done well to increase productivity and double the income of farmers participating in the project within two years in Kenya and it also promoted to more than twenty African countries including Ethiopia and South Africa. The OVOP project has supported Malawian farmers to develop various products including baobab oil, pot stand, and Moringa powder [59].

4. Opportunities and Challenges in Agricultural Technical Cooperation Projects

In this section, three case studies in agricultural technical cooperation projects are discussed to draw experiences of agricultural technology transfer to Africa. The section presents mechanisms, achievements as well as challenges of the ATDC project as one of the case studies in China–Tanzania agricultural cooperation projects, followed by Japanese SHEP project in Kenya and RIDS in Tanzania.

4.1. Case Study 1: Supporting the Adoption of Agricultural Technology Through ATDC in Tanzania

The Chinese agricultural technology demonstration center (ATDC) intended to share China's experience in agricultural technology so as to promote agricultural technology diffusion in Africa countries. The ATDC in Tanzania was established in 2009 to 2011 in Dakawa, nearby Dakawa Agriculture Research Institute, and operated by Chinese enterprise (Sino-Tanzania Agricultural

Development Co. Ltd., Chongqing, China) and the Chongqing Academy of Agricultural Sciences in China, in partnership with the Tanzanian Ministry of Agriculture, Food Security, and Cooperatives (MAFC). The total area of 62 ha includes office and training area (2 ha), experiment and display area (10 ha), and production and demonstration area (50 ha). The ATDC tasked to provide a demonstration of improved cultivars, agricultural practices, and train local farmers and technicians about Chinese agricultural technologies, particularly rice. Therefore, ATDC in Tanzania focuses on rice, with various trials and demonstrations of the ten different hybrid rice cultivars from the Chongqing Academy of Agricultural Sciences [9,60].

The agricultural technology demonstration center (ATDC) phased in three stages which include the two years of the construction stage, the three years of technical cooperation, and then business operation stage. The technical cooperation stage implemented three main functions: Experimental studies, technology training, and promotion through demonstration. In the experimental part, the ATDC tested and introduced new varieties and farming practices to community farmers. The training plan involves classroom, on-site, and video teaching which covers a broad range of skills related to sowing and paddy preparation, leveling, and water lodging prevention, nursery management, transplanting techniques, management of the soil nutrients, and input application. Moreover, ATDC promotes modern agricultural equipment from China, such as tractors, hollows, plows, and rice harvesters to encourage farmers to purchase similar products. In the business stage, the ATDC is expected to mature enough to establish a market-oriented operation and integrated agribusiness value chain, hence sustain the ATDC without fund support from China government. At this stage, the Chinese company continues taking full charge of the ATDC's management while relying on incomes from the business operation. The business model in aid management adopted to ensure the sustainability of agricultural aid, following China's aid reform history in the 1980s, domestic development experience, and "going global" strategy [31,61].

The agricultural technology demonstration center (ATDC) has revealed the achievements of Chinese agricultural technologies to transform rice production however, the ATDC faces challenges that may question its sustainability and effectiveness in the long run. The Chinese hybrid rice from Chongqing academy could reach 9–12 t/ha under the same management conditions while the local rice varieties were ranging 0.8–4.5 t/ha, following the series of trials in Dakawa, Katrin, Rufiji, and Mombo sites. Furthermore, it was noted that the Chinese farm technology alone could contribute 20% to 30% of improvement in productivity for the local rice varieties compared to traditional methods. For instance, local rice farmers were excited to see a yield of 7 tons/ha from TXD 306 at the ATDC facility, which had yielded only 4 tons/ha at their farms. In contrast to ATDC in another part of Africa such as Nigeria, [62] from the Foreign Economic Cooperation Center of China's Ministry of Agriculture noted that China's cultivation techniques save up to 30% of the seeds, seedbeds, and transplantation, and increases up to 18% of rice yields in comparison with the local technologies. The technology selection in the ATDC was driven by yield performance, and rice-planting practices mainly focused on row-planting spacing and fertilization, while more than 900 farmers attended such training.

Nevertheless, the ATDC in the business stage is facing inadequate profits while the mechanism of disseminating agro-technology and surrounding institutional environment may limit the successful diffusion and utilization by targeted farmers. Chinese rice varieties are patented by the Chongqing Zhongyi Seed Company in China, and therefore narrow the possibility of seed adaptation to a new environment. ATDC is now bound to import seeds from China, however, there is still a notion that Chinese rice varieties are technically excellent but not as good as the local variety in terms of taste and aroma [31]. If the notation holds true, it may affect the marketability of Chinese imported rice seeds and automatically harmer the profitability and commercialization plan of ATDC in the business stage. To this point, it is worth noting that the influential drivers for local farmers do not only depend on yield performance but also the influences of market demand in terms of consumers' preferences for rice attributes [63]. This necessitates Chinese rice varieties to adapt to the local market condition and consumers' demand as well for ATDC sustainability and effectiveness. Thus, joint research programs with national agriculture research institutes are recommended to enhance innovation and technology transfer to farmers. Notwithstanding, Tanzanian seed protection policies and regulations control seed imports however it offers a roadmap for the variety release and registration process, certification process, and other regulatory aspects of seed sector development which take processes and time in implementation [64]. On the other hand, the absence of local seed breeding collaboration projects as observed by [60], may hinder innovations and transfer of technical know-how from Chinese researchers to local partner researchers. Inadequate engagement and links between ATDC researchers with local key stakeholders in the area may affect farmer participation in the ATDC project in the long run as well. So far, the ATDC business operation stage is relying on created market demand during technical cooperation stage, however, there is neither formal plans nor enough efforts to create such demand in Tanzania, while the level of ATDC interaction and communication with farmers remains inadequate and the Chinese team lacks a clear plan for the center and outreach to other local farmers [31,65].

4.2. Case Study 2: Supporting Horticulture Production through SHEP in Kenya

The Smallholder Horticulture Empowerment Project (SHEP) was established in 2006 in Kenya to encourage smallholder farmers to conduct market surveys and grow profitable horticultural crops according to market demand. The SHEP is a technical cooperation project with Japan that aimed to address the challenges of stagnant subsistence-based smallholder horticulture by empowering smallholder farmers to cope with market-oriented agriculture while improving their incomes and productivity. This project has been implemented jointly by the State Department of Agriculture, the Ministry of Agriculture, Livestock and Fisheries (MOALF), the Horticulture Crops Development Authority (HCDA) in Kenya, and the Japan International Cooperation Agency (JICA). In Kenya, at least 2.5 million people are employed within the horticultural sector making it one of the largest foreign exchange earners [66]. However, the majority of smallholder farmers faced poor crop productivity and low farm income. Thus, the government of Kenya conceived the idea of the project and requested Japan's support to implement a technical cooperation project, which was then called Smallholder Horticulture Empowerment Project (SHEP) [67].

The SHEP capacitated smallholder farmers in market-oriented horticultural farming and production techniques in order to produce as per market requirements. SHEP confronts market inaccessibility challenge by strengthening farmers' capacity in marketing and horticulture production aspect, to prepare farmers to be successful in agribusiness. The project trains farmers to do their own market research and strategic selection of crops to plant, based on the market signal, development of action plans by farmers' groups, and apply agricultural techniques practices. Likewise, SHEP alerted the stakeholders' platform to communicate the idea and facilitate interaction among all horticulture value chain actors while establishing the joint extension staff and farmers' dual, and demand-driven technical training [55,67,68].

The SHEP achieved double earnings for Kenyan farmers who participated in the project, and marked the lesson for expansion in countrywide and another part of Africa. The SHEP has done well to encourage the various actors to act proactively driven by their intrinsic motives to realize increased farm-household incomes. It has alerted the smallholder farmers to stick to market demands and requirements while remaining linked to the value chains. The SHEP based on motivation theory influenced the changes in a stakeholder's mind and behavior, and eventually, made them intrinsically motivated for enhancing sustainability and the sense of creativity. It enabled farmers to envision how, when, and where their own crops will be traded. The authors such as Sayanagi and Aikawa [45] have found that the values underlying SHEP activities have indeed been internalized, and therefore, SHEP participants including field officers and farmers, are autonomously motivated to continue SHEP-related activities even after the program ends. The SHEP approach may imply that, in the technology transfer process, competence support is required to come before autonomy supports, but the connection between the two in supporting context is necessary for behavior to be enacted and sustained. In agricultural technology transfer, it is therefore important to analyze the degree of technical need support, but also identify deficits in technical need support and ways to improve. Moreover, the SHEP project team was established as a project unit, that comprises the Japanese experts and full-time staff assigned from the Ministry of Agriculture down to the farmers, and the roles and responsibilities of each actor were clarified ready to undertake actions. SHEP may also suggest the importance of a strong linkage of all stakeholders, to achieve long-term sustainable agricultural development. On the other hand, SHEP shortlisted among the successful project, was well received by the Kenyan government and other donors due to its unique approach and innovation in agriculture technical transfer. Yet, the challenge remaining is individualistic marketing which results into the low supply of the produces and bargaining power for a better price [44,45,67,69].

4.3. Case Study 3: Supporting Rice Production through RIDS in Tanzania

Japan supported the technical cooperation in Tanzania through Rice Industry Development Support (RIDS), which has involved more than six technical cooperation projects in the rice sector where five of them, were implemented in the Kilimanjaro region in Tanzania. The RIDS designed to increase the rice productivity and income by improving irrigation infrastructures and the dissemination of appropriate rice production technology as the average national productivity per hectare remains low (1.6–2.4 t/ha) due to production constraints and unstable rainfall. In the implementation of agricultural technical projects, Japan International Cooperation Agency (JICA) collaborates with national agricultural researches and training institutes under the Tanzanian Ministry of Agriculture, Food Security, and Cooperatives (MAFC). The agricultural technical assistance includes the large-scale irrigated rice production undertaken in the Kilimanjaro area at Lower Moshi since the 1970s and various participatory small-scale irrigation projects [44,49,51,70].

The Japan technical cooperation in RIDS had various implementation phases over time. It began with Kilimanjaro Agricultural Development Center (KADC) construction that ended in 1981. The second phase extended to 1986 to prepare fields suitable for paddy farming under Kilimanjaro Agricultural Development Project (KADP). The preparation for paddy fields and farm infrastructure including irrigation and drainage networks completely finished by 1987 and followed by technology transfer in paddy cultivation, agricultural mechanization, and water management techniques from 1987 to 1993. The planning and construction for the Kilimanjaro Agricultural Training Center (KATC) project implemented from 1994 to 2000 under Japan grant aid. Based on the experience of KADC and KADP in Lower Moshi, the KATC established to expand irrigated paddy cultivation technology at a national level.

The KATC inaugurated various training programs for farmers and agricultural extension officers, which then includes the joint technical training of farmers and extension officers; and the farmer-to-farmer extension of the cultivation techniques. By 2001, about 1997 participants (extension officers and key farmers) attended the KATC training [50]. From 2001 to 2006, the KATC began another technical cooperation project to disseminate the rice technology to six irrigation schemes where five of the schemes improved the paddy rice yield from 3.1 to 4.2 t/ha [51]. Since 1981 when the full rice technical transfer began in Tanzania, at least 50 JICA experts have been dispatched to conduct local training for short-term and long-term assignments, and some Tanzanians received training in Japan. The cooperation of Japanese experts and local staffs in Lower Moshi project established agricultural technology such as the selection of appropriate paddy varieties; the standard for paddy cultivation; schedules for water distribution; and method of cultivation. The outcomes in the agricultural sector during the evaluation period included both an increase in rice production volume and an increase in rice productivity in Tanzania. Likewise, the total area of newly irrigated land also increased annually [71]. The authors of [72] found that agronomic practices taught by Japan training in Tanzania play key roles in increasing the adoption of modern technologies and the productivity of rice farming in the targeted areas, however other factors such as access to water and rice buyer also determine the adoption of using a given technology.

A series of projects in RIDS have made a substantial improvement in agricultural productivity, income, and impact in the living standards of farmers who participated in the technical project. The income of the farmers increased up to 6.3 times, while rice productivity improved from 1.5 to 6.5 t/ha in Lower Moshi [46,47]. In contrast, the Lower Moshi projects in Kilimanjaro are considered as an example of remarkable technical cooperation of Japan and Tanzania, and the KADC viewed as the core of rice technical training for farmers and extension workers. However, KADC has been criticized for excluding farmers' views from the beginning of the project [47,73]. The KADC lacked autonomy despite having been high in terms of the technical aspect. During the end of technical transfer phases in 1993, the rice farmer's organization (CHAWAMPU) formed to manage the KADC project, but nevertheless, it lacked managerial skills and autonomy as it was formed during project termination. The KADP operation then again relies on support from JICA experts and local government whereby few members of CHAWAMPU could neither raise sufficient operations fund nor afford spare parts for tractors donated [48].

5. Success Factors for the Sustainability of Technology Transfer Projects

In this section, we identify the main success factors from the case studies and literature that must be considered to ensure the sustainability of agricultural technical projects:

- Community participation in technical cooperation projects;
- Stakeholders linkages, supports, and commitment to achieve a common objective;
- Perceived benefits of transferred technology in the local community;
- Identification of project environment and nature of agricultural technical project to incorporate sustainability (i.e., nature of technical project versus local environment);
- Fostering autonomy, self-reliance, and utilization of local resources in a technical cooperation project.

5.1. Community Participation in Technical Cooperation Projects

Participation of the intended community in technical projects is important not only for promotion but also for the sustainability of project management in the local environmental context. However, community participation goes beyond this scope by engaging community to identify their needs, plan, mobilize, and execute solution to these needs [74,75] For this case, a project well linked to local community participation may enhance the diffusion process of transferred technology while offering an opportunity to experiment with its use, as revealed in the SHEP case project in Kenya. The extent of community participation may also mean to stimulate the local demand of transferred technology. Therefore, a limited opportunity by farmers to try the Chinese hybrid rice seed in their farms during the technical period, may not be enough to stimulate the local demand which may sustain the ATDC in the business stage. On the other hand, ATDC may consider massive farmers' participation, such as the farmer-to-farmer extension of the cultivation techniques employed by RIDS in order to enhance the adoption and sustainability of ATDC in the business stage, especially when Chinese seeds registration and certification requirement are fulfilled in Tanzania. According to [72], technologies taught by JICA gradually diffused from directly trained key farmers to other farmers, which suggests the effectiveness of the farmer-to-farmer extension mechanism.

5.2. Stakeholders Linkages, Supports, and Commitment to Achieve a Common Objective

The authors of Dahiya and Okitasari [76] defined stakeholders as any individual, organization, sector, or community that has a "stake" or interest in the outcome of a given decision, process, or partnership. In agricultural technical projects, stakeholders' groups may include government and non-governments organizations, farmers, extensions, researchers, inputs suppliers, traders, and other service providers. According to [77], stakeholders can affect an implementer organization's functioning, goals, development, and even survival because of their unwillingness to continuously support the vision or objectives of the project which leads many projects to fail. In general, different stakeholders have different levels and types of investments/supports and interests in the project, which sometimes results in conflicts among the stakeholders [78]. Still, the project's stakeholders are vital to ensure the sustainability of project benefits only if when they are well linked together to work, to devise, to plan, and to develop solutions that achieve a common objective [79]. Moreover, the engagement of project stakeholders may facilitate the achievement of objectives that cannot be accomplished by working in isolation from other potential partners. However, stakeholder participation must be based on the principles of voluntary involvement to allow full commitment to the course and full participation [80].

In the case of bilateral technical cooperation projects, governments' commitment, and participation of all key stakeholders in the design and implementation of the technical project is essential for enhancing the effectiveness and sustainable impacts of technical cooperation in the recipient countries. For instance, the technical cooperation in case studies was implemented by collaboration with local government, nevertheless, the participation role of all key stakeholders in the project unit is highly important. In the case of SHEP success in Kenya, the roles of government and other stakeholders are highlighted [67]. The Ministry of agriculture was fully aware and committed to take a certain amount of time for people's capacity development, which implies the necessity of government commitment to enhancing successful agriculture technology transfer. Yet, as a technology recipient country remains the initiator of technical project process (i.e., a technical cooperation which is based on the request basis principle), the local government should have a clear vision of the roles to be played by the administration and other stakeholders, what agricultural technology is needed in local community, and how to implement it to achieve such a vision. In the same way, the administration must have a profound understanding of how commercial agriculture works for technology transfer to remain effective and sustainable for years.

5.3. Perceived Benefits of Transferred Technology in the Local Community

A project that does not meet the economic needs of the local community will quickly become irrelevant and the community will lose interest in it [81]. Even if measuring project outcomes is a complex process as it requires proof of correlation to, and causation from, the respective project outputs, still, the perceived benefit of transferred technology matters for project sustainability [82]. In most cases, farmers perceive the benefits of agricultural technology in terms of input–cost, inputs–output, and output–profit relationships. Therefore, the ability to define the benefit of a project to the beneficiaries and focus on achieving these benefits will determine the sustainability of the agricultural technical projects. The benefits of a technology transfer project can be seen as positive and valuable outcomes that are desirable to the project stakeholders. In fact, any project team that just focuses on the quality, time, and cost indicators only without a focus on economic benefit to the community may experience unsustainability, because, it is only when local stakeholders appreciate the benefits, they will mobilize resources to guard the project and ensure continuity [83].

5.4. Identification of the Project Environment and Nature of Agricultural Technical Project to Incorporate Sustainability

All projects take place within a strategic context, and there are both internal and external environmental factors that surround or influence a project's success. Thus, consideration of these factors may enhance or constrain project management options and therefore affect the benefits of the transferred technology. For ensuring project sustainability, it is worth considering the project's future orientation, and therefore the balance between cost, schedule, and scope must be made between the economic, social, technical, legal, institutional, and environmental factors surrounding agricultural technical project [84]. For instance, in our case studies in Tanzania, we found that water shortage and operation cost of the irrigation scheme affected the effectiveness and sustainability of the technical cooperation project benefits. When ATDC faces high operation costs of the irrigation system during the technical cooperation stage, the ability to self-sustain at the business stage may be affected as well. Likewise, water shortage in an irrigation scheme in the Kilimanjaro Agricultural Development Project (KADP) of RIDS affected the growth of farmers' organization (CHAWAMPU) as farmers did not get incentives from paying a membership fee, where rice cannot actively cultivate [48]. Such a challenge may point to the necessity of identifying the site selection as well and anticipate challenges and solutions, even before the project implementation. Therefore, deep analysis is recommended in feasibility analysis to incorporate project sustainability and effectiveness from the identification stage, design, and implementation.

5.5. Fostering Autonomy, Self-Reliance, and Utilization of Local Resources in a Technical Cooperation Project

Introducing a technical cooperation project that relies heavily on imported raw materials challenges the same balance of resources that a transferred technology seeks to improve [85]. The author of Sneddon [81] noted that a project will only be sustained if it uses locally available resources that include manpower and technical knowhow. When a combination of local inputs are converted by technical know-how (i.e., transferred technology), the project benefits are produced that meet the needs of the community. Attaining sustainability of project benefits, may require a model based on inputs from the local environment while maintaining a feedback relationship between the inputs and the outputs through the structures, technology, culture, and process [86]. Thus, transferred technology should adapt to the local environment and community demands while ensuring the desired outputs. To enhance adaptation, the technology transfer protocol includes intellectual property right that should be addressed. According to [87], intellectual property rights may affect the flexibility and adoption of technology, especially in developing countries. Nevertheless, technology matters most if it is affordable and if it is appropriate to scale and conditions [88]. For this case, equipping beneficiaries groups to become self-reliant in the aspect of technical knowledge, skills, and capacity to serve the project in the long run is important for the enhancement of sustainability. As one of the slogans say "it is worthwhile training how to fish than to give a fish or help to fish", which implies that technology transfer on how to fish may enhance the self-reliance of the recipient of technology for a lifetime. In the case of local farmers, [72] have revealed the necessity for farmers to have sufficient knowledge of transferred technology as it may be diffused slowly from the key farmers to intermediary and ordinary farmers. Following [68], the SHEP team of experts provided intensive training to the farmer's groups on how to execute the step and what outcomes to expect while offering the detailed rationale to do so, which built competence and sense of autonomy.

6. Interaction of the Key Success Factors in System Dynamic Complexity

Another parameter that affects the sustainability of technical cooperation projects is the interdependency of key success factors (Section 5). As illustrated in the causal loop diagram (CLD) (i.e., Figure 6), in nature the aforementioned factors interact with each other with dynamic complexity. Sustainability of any project results from the extent by which the local community keeps participating in a project to realize the intended benefits after the project intervention period. However, the participation of the local community and other stakeholders may be influenced by the perceived benefit of the transferred technology. For example, farmers may keep comparing the tradition versus new technology to decide whether to continue or abandon the transferred technology. Likewise, the project environment; commitment and linkage of stakeholders; autonomy support, self-reliance, and local resources utilization during project intervention may result in community participation. Notwithstanding, the benefit of transferred technology may result from project environment; stakeholder's commitment/supports, and resources available, while appropriate project environment may well be determined by involving project beneficiaries, which include local community and other stakeholders. On the other hand, autonomy comes from the extent by which the beneficiary community was involved in all stages of the project cycle, while self-reliance and utilization of local resources may either be a result of stakeholders' linkages, supports, and operating project environment. This explains the CLD features that considerably influence the behavior of project sustainability.

In turn, the improvement of sustainability of agricultural technical cooperation projects is vital for enhancing perceived benefits of transferred technology in local community, increasing community participation, self-reliance, and local resources utilization. Taking a system approach, all factors are related, which suggesting any negative changes of one factor may result in the unsustainability of technical cooperation projects. The balancing loop suggests that an increase in sustainability of agricultural technology projects will improve the level of agricultural productivity, and therefore reduce dependence of agricultural technology transfer from abroad: The more improvement of agricultural productivity, the less technical transfer needed to improve such situation. On the other hand, CLD points that project sustainability is not resulting from one factor, therefore the implementers of technical cooperation projects should embrace a system thinking approach to incorporate a multidimensional factor that may enhance project sustainability. Increasing in agricultural technology transfer means fostering more technical cooperation projects in the agriculture sector. However, it is important to establish a project sustainability management system and decision-making processes to enhance the sustainability of technical cooperation projects.

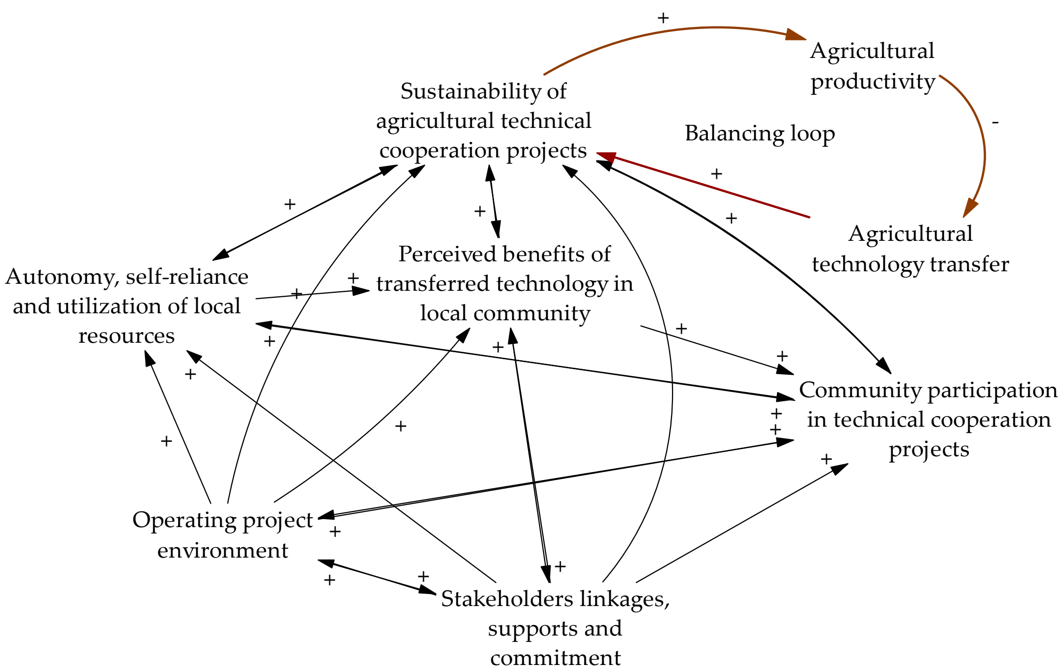

Figure 6. A causal loop diagram for the sustainability of technical transfer cooperation projects.

7. Conclusions

China and Japan's experiences in technical transfer disclose how agriculture technology transfer is critical in improving productivity and farm income. The technical cooperation in rice sectors in Tanzania and horticulture in Kenya is such a good lesson for agricultural technology transfer toward efforts of eradicating poverty and food insecurity in Africa. It should be noted, however, that, for sustainability and effectiveness, the system thinking approach should be taken into account to incorporate multifactor which by interaction, they may affect project sustainability. Yet, the agricultural technology transfer requires strong participation and linkage of all stakeholders from designing to the implementation stage. On the other hand, technical cooperation may require deep analysis to include project operating environment in the recipient country, if necessary. Likewise, it is worthwhile to incorporate views of smallholder farmers in decision making if they are the targeted users or beneficiaries of the agricultural technology transfer project. Doing so is essential for creating a sense of ownership, autonomy, and even encourage the innovations of the smallholder farmers. Nevertheless, understanding the smallholder farmers' motivation, and how farmers evaluate the technologies transfer in terms of technical feasibility and economic viability is important for enhancing the sustainability of transferred technology. Yet, the technical cooperation counts on government commitment and strong linkages and participation of both stakeholders while the responsibility of each key stakeholder is administered.

The government support is imperative in the commencement of technical cooperation projects and the diffusion of technology. The availability and accessibility to better technology in the locale may enhance a farmer's adoption of better technology. However, the technology transfer mechanism and the potential of technology to meet farmers' short-term and long-term goals may intrinsically motivate the continued utilization of agricultural technology. Thus, it is worthwhile if the transfer of technology is localized to reflect the farmers' and consumers' demand in order to create incentives for private sector engagements as well. Further studies are however recommended to improve the agricultural technology transfer mechanism that fits well to equip beneficiary autonomy in terms of knowledge and capacity of production in the recipient country. The local governments need to set policy environments and institutional frameworks that encourage and support the agricultural technology transfer to benefit the rural farmers. Above all, in transforming agricultural sector growth, the strong commitment of both, the technology recipient country and the players in technology generation are prerequisites and may involve a long-term investment in agriculture technology transfer from the initial stage to maturity.

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