Food and Agriculture Organization
of the United Nations

AN INNOVATION IN AGRICULTURAL SCIENCE AND TECHNOLOGY EXTENSION SYSTEM

CASE STUDY ON SCIENCE AND TECHNOLOGY BACKYARD

OCCASIONAL PAPERS ON **INNOVATION IN FAMILY FARMING**

AN INNOVATION IN AGRICULTURAL SCIENCE AND TECHNOLOGY EXTENSION SYSTEM

CASE STUDY ON SCIENCE AND TECHNOLOGY BACKYARD

Prepared by

Research and Extension Unit (OINR),
Office of Innovation, FAO

P. Yang, X. Jiao, D. Feng, S. Ramasamy,
H. Zhang, Z. Mroczek and W. Zhang

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2021

Required citation:
Yang, P., Jiao, X., Feng, D., Ramasamy, S., Zhang, H., Mroczek, Z. & Zhang, W. 2021. *An innovation in agricultural science and technology extension system – Case study on science and technology backyard*. Rome, FAO. https://doi.org/10.4060/cb2939en

ISBN 978-92-5-133870-4

Cover photo:
African graduate students in China Agriculture University in the 2020 science and technology backyard program in China.
© Kun Sang

CONTENTS

Figures

Boxes

ACKNOWLEDGEMENTS

This publication was prepared as a case study report on the science and technology backyard. The science and technology backyard is a scheme designed to enhance community-driven linkages between education, research and extension to provide agricultural extension and advisory services (AEAS) to smallholder farmers, and has been improving ever since. The science and technology backyard is also used as a key intervention tool on agricultural development projects for smallholder farmers to support agricultural innovation systems.

In 2009, professors and postgraduate students from China Agricultural University (CAU) moved their research programs from the experimental station in Quzhou county of Hebei province to Beiyou village of Baizhai township in this county. In the village, they rented a backyard where they lived, worked and studied. Intensive day-to-day farmer participatory training was also conducted there by professors and postgraduate students. Gradually, the yard attracted increasing farmer participation. With increasing numbers of farmers turning up for help and technical consultations when they encountered agronomy problems, the yard became a science and technology dissemination focal point in the local community. From then on, farmers called it the science and technology backyard. Over the years in China, science and technology backyard was used to identify multifaceted production-limiting factors involving agronomic, infrastructural, and socioeconomic aspects by participatory approaches. Chinese farmers played an active role in finding and co-developing their own solutions. They adopted a number of agricultural innovations, thereby improving production outcomes. An account of the efficiency and effectiveness of science and technology backyard in closing yield gaps between smallholder farmers' actual and potential yields, based on large-scale scientific research results and advancements in China, was published in 2016 (Zhang *et al.,* 2016). Science and technology backyard has attracted international attention as an innovation platform in the agricultural science and technology transfer system, and is considered to have great potential in terms of adoption and scaling up. The ultimate aim is to promote research-triggered agricultural innovation in addressing global agricultural challenges such as food insecurity, environmental degradation and climate changes.

This report was prepared by Puyun Yang, Xiaoqiang Jiao, Dongxin Feng, Selvaraju Ramasamy, Hongyan Zhang, Zofia Krystyna Mroczek, and Weifeng Zhang, and based on a joint case study on science and technology backyard by Food and Agriculture Organization of the United Nations (FAO) and CAU in 2020.

The authors would like to specifically acknowledge professors Fusuo Zhang, Xiaolin Li, Rongfeng Jiang, Chong Wang, Fanjun Chen, Chaochun Zhang, Chengdong Huang, and Jianbo Shen and numerous postgraduate students in CAU for their key contributions to the development and improvement of science and technology backyard. The authors are grateful to Nevena Alexandrova, Delgermaa Chuluunbaatar and Sonia Dias of FAO OINR for their inspiring comments and suggestions on the development of this report.

Finally, the authors would like to thank Studio Bartoleschi for design and layout, Andrew Morris for final editing, and Selvaraju Ramasamy for publishing oversight.

ABBREVIATIONS AND ACRONYMS

AEAS	agricultural extension and advisory services
CAU	China Agricultural University
CNY	Renminbi Yuan (1 CNY=1/7 US$)
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field school
ICT	information and communications technology
ISSM	Integrated Soil-Crop System Management
MU	Unit of Acreage (1 Mu=1/15 Hectare)
NGO	non-governmental organization
OINR	Research and Extension Unit, Office of Innovation, FAO
SDG	Sustainable Development Goal

© Yu Guo

CHAPTER 1

INTRODUCTION

Food production worldwide is primarily carried out by smallholder farmers. Closing the gap between actual smallholder yield and those achievable through scientific research is vital to increasing the food availability and efficient use of inputs and natural resources. The magnitude of the production gaps is particularly large in developing countries, where smallholders face multiple challenges (Chen *et al.,* 2014; Tilman *et al.,* 2011; Zhang *et al.,* 2016). Multiple factors and constraints contribute to these production gaps, including uncoordinated linkages between education, research and extension. The linkages between education, research and extension are often supply-driven and top-down, and unable to respond to the diversity of location-specific, locally-adaptive and multiple knowledge demands – as smallholders are a diverse group in terms of incomes, knowledge, perceptions and farming practices. Furthermore, researchers and educationalists in universities and research institutions and extension services in most developing countries seldom have a good understanding of the actual issues faced by farmers. Linkages between research, education and extension are weak and their services are therefore not well connected with the needs of farmers. Innovative approaches must be strengthened to enable smallholders to achieve economic, environmental and social gains sustainably from agricultural science and technology research and educational advancements.

In 2005, China Agricultural University (CAU) launched a pilot agricultural development project in partnership with Quzhou county in Hebei province of China to work together to develop high-yielding technologies. The focus was on plant nutrient management and the efficient use of fertilizers to increase smallholder production capacity through sustainable crop intensification. From 2009 onwards, CAU professors and postgraduate students working in Quzhou started promoting these high-yielding technologies through agricultural extension and advisory service (AEAS) including farmer participatory surveys, research and training. It was found that through AEAS, the adoption of high-yield and high-efficiency technologies (e.g. formulated fertilizer, sowing technology, and techniques of efficient use of water and fertilizer) by recipient farmers was much higher than by conventional farmers. This therefore inspired the professors and postgraduate students to further strengthen their engagement with farmers and to spend time living in the local community alongside the farmers, communicating with them, and sharing in their successes and failures (Zhang *et al.,* 2016; Jiao *et al.,* 2019). In 2009, CAU professors and postgraduate students moved their research programs from the experimental station to the village, and rented a backyard, where they lived, worked and studied high-yielding technologies and responses

On the left page: the graduate students celebrated good harvest of grapes of the science and technology backyard demonstration farm (2020).

from the farmers. Gradually, their backyard work attracted more farmers and encouraged their participation. The backyard thus became a science and technology dissemination platform in the local community. From then on, farmers, scientists and students referred to the project as the science and technology backyard.

The numbers of science and technology backyards, farms covered by science and technology backyards and farmers trained all have increased rapidly since its beginnings in 2009. In 2020, 127 science and technology backyards covering 45 kinds of major crops have been established and continue operating in 23 provinces and regions with the participation of 29 scientific research institutes and over 100 agricultural extension stations in China. Under the support of the Bill & Melinda Gates Foundation in 2019, FAO and the World Bank established a partnership program between CAU and a number of African countries, promoting the science and technology backyard approach in order to enhance the transformation of Africa agriculture, 34 students from eight African countries have been recruited and have received training from CAU. The students will return to their countries in 2021 for future implementation of science and technology backyards.

Agricultural education, research and extension are the three main pillars for supporting sustainable agricultural development. The science and technology backyard, a kind of multi-actors innovation platform enables the scientific community, including research, education and technology application and extension sectors, to work together in conjunction with farming communities to facilitate knowledge generation, transfer and information exchange and agricultural innovation. Science and technology backyard is a newly developed approach, which brings educationists, researchers, extension agents and farming communities together in a collaborative research context to address farmer-specific practical problems (Zhang *et al.,* 2013; Shen *et al.,* 2013; Zhang *et al.,* 2016). The science and technology backyard has worked successfully in China and has started to be adopted in some African countries, but is yet to be tested in many other countries facing similar challenges. This case study on the science and technology backyard highlights important implications for further scaling up this model. It also documents important experience and the lessons learned, with a view to determining the conditions and factors that need to be taken into consideration for both public and private investments, while facilitating agricultural technology transfer and innovations in rural communities. This case study, elaborated jointly by Research and Extension Unit (OINR) of FAO and CAU, aims primarily to evaluate the relevance, effectiveness and efficiency of the science and technology backyard in agricultural technology transfer and innovations, and to highlight the necessary implications for judging whether the science and technology backyard should be invested and institutionalized as a new model for AEAS. It also pinpoints the challenges and constraints of scaling-up and institutionalizing science and technology backyard.

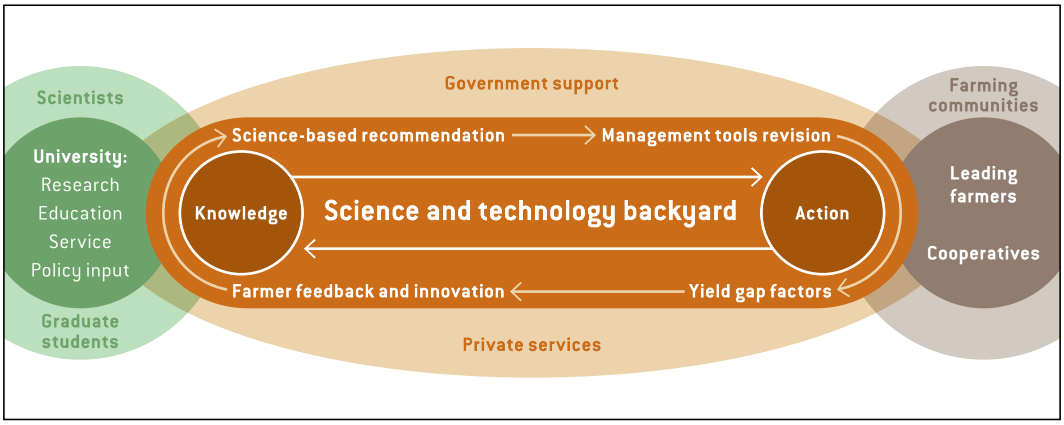
CHAPTER 2

SCIENCE AND TECHNOLOGY BACKYARD

2.1. CONCEPT MODEL OF THE SCIENCE AND TECHNOLOGY BACKYARD

The science and technology backyard is a platform, located in rural areas, which links students, researchers, extension agents and smallholders (also including local government and private enterprises), in order to facilitate information exchange and technological innovation in agriculture (Fig. 1). In the science and technology backyards, agronomy professionals (experts), including researchers and postgraduate students live in the backyards of smallholder farms and work together with farmers and extension agents. Farmers are trained and knowledge is transferred through the multi-actors innovation platform, consisting of farmer field schools (FFS), participatory on-farm research, new technology demonstrations and farmer interest group or clubs. Consequently, when farmers encounter agronomy problems, they access the services of scientists and experts without delays, limitations, extra fees or travel time. In addition, a new and effective system of technological innovation and extension is explored through involvement of university staff and students, and local extension agents.

Figure 1. Concept model of the science and technology backyard



Source: Zhang *et al.*, 2016.

2.2. COMPOSITION OF THE SCIENCE AND TECHNOLOGY BACKYARD

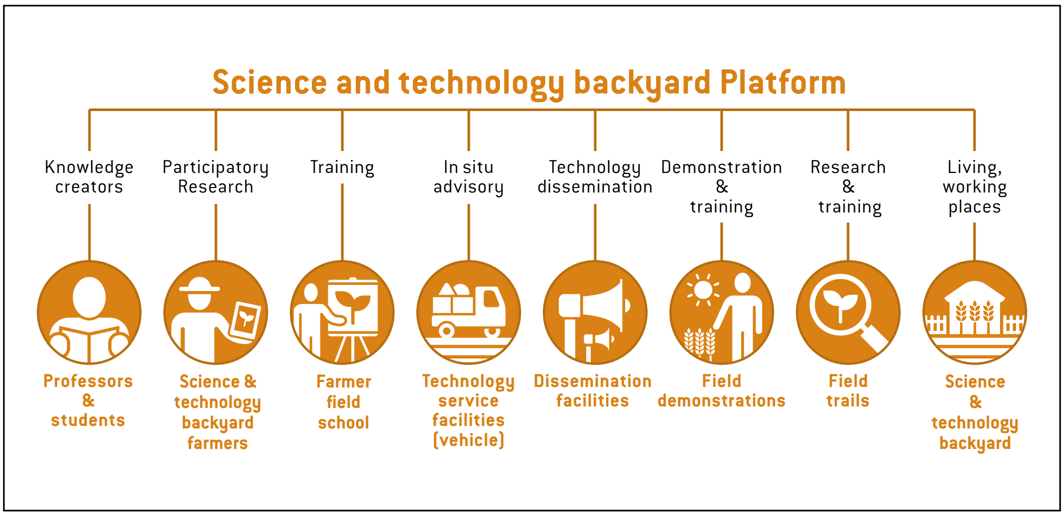
A typical science and technology backyard consists of the following components: a backyard, professionals, a group of leading farmers, training and technological service facilities (e.g. public address systems, computers, projectors, motorized tricycles and brochures), experimental plots and demonstration plots (Fig. 2).

(1) A backyard: Science and technology backyards are located in rural areas, a house for the accommodation of professionals (professors and postgraduate students) is rented or built in rural communities, which local farmers can easily access, for the purpose of enhancing the engagement and communication of professionals with farmers. In many science and technology backyards, the best option is to live in village committee offices, which are usually located at the centre of farmer communities, where farmers gather most frequently in their daily life. It is convenient for the professionals to communicate and build up mutual trust with local farmers and local government departments.

(2) Professionals: Each science and technology backyard is staffed with at least two postgraduate students and one supervisor (professor or teacher). Another extracurricular mentor may be included if the conditions of the backyard allow. Two postgraduate students team up in each science and technology backyard to help and encourage each other. The professor in the science and technology backyard is usually the mentor of the two postgraduate students, and is responsible for coaching the postgraduate students to conduct on-farm participatory research and communicate international and national advanced research. Extracurricular mentors in the science and technology backyards are usually local leaders, local entrepreneurs or extension specialists who provide needed support for the postgraduate students to conduct activities in rural communities. Extracurricular mentors like local leaders can provide better resources for organization and coordination, entrepreneurs can assist with solving financing problems, and extension specialists can provide practical technologies.

(3) Experimental plots: In the science and technology backyard, experimental fields are established to integrate new technologies designed to solve the key problems of local agricultural production and jointly innovate the most feasible and location-specific solutions. The fields belong to farmers, and the science and technology backyard pays rent or collaborates with farmers to conduct experiments. The farmers participate in some field management, and sometimes provide input from their own experience. During the experiments, farmers are fully exposed to the new technologies, thus providing opportunities to learn from participatory experiments. This kind of on-farm participatory research is the first step for science and technology backyard innovation.

Figure 2. Composition of a typical science and technology backyard



(4) Demonstration plots: Demonstration plots are supervised by the science and technology backyard, but normally managed by a lead farmer (who usually has better skills, and is open to change and trusted in the village). Demonstration plots are used for packaging and integrating key technologies and practices developed from the on-farm research or introduced by the science and technology backyard. However, their most important function is to provide farmer experience and locally adapted technologies. The joint efforts of science and technology backyard and lead farmers greatly improve the adaptability and integrated efficacy of new technologies. The demonstration plots are also a platform to involve government extension systems to demonstrate new products.

(5) Research equipment and training facilities: In the science and technology backyard, a motorized tricycle is used for transport, and research equipment, including soil and plant nutrient quick-testing toolkits, digital cameras and other experimental and research tools are provided for field experiments and trials. Training facilities are equipped in the science and technology backyard, which include at least one classroom for holding farmer training courses, computer projectors, public address systems and other necessary facilities. Field training facilities are also established in the experimental and demonstration plots, which mainly consist of a series of poster stands or display boards for technology and practice demonstrations.

(6) Lead farmers: Lead farmers receive training in the science and technology backyard. They are interested in AEAS and enthusiastic to work with the professionals in the science and technology backyard to conduct field trials, technical demonstrations and farmer training. After training in the science and technology backyards, lead farmers are empowered to work with professionals to conduct on-farm participatory research and technical demonstrations and facilitate farmer training activities.

2.3. MAIN ACTIVITIES OF THE SCIENCE AND TECHNOLOGY BACKYARD

The description, explanation, exploration and design model is adopted by science and technology backyard staff to conduct research designed in the villages. Farmer practice in their own fields is systematically described by science and technology backyard professionals or farmer technicians through survey and real-time tracking data. Professors and students living in the science and technology backyards provide detailed explanations of farmer practices. The performance of these practices is in turn explored systematically with various tools, such as model analysis. New choices and configurations and the associated technologies are designed by the professors and students in the science and technology backyards. This research methodology links the extension system closely with farmer fields. Finally, the problems encountered by farmers in their own fields are solved and a new model of technology transfer is developed for wider adoption.

In detail, the description, explanation, exploration and design concept is implemented through the "1351" action model (a village surveyed by professionals, 30 farmer families, 50 farmer field plots and a 100-mu demonstration field; 15 mu = 1 ha) (Jiao *et al.,* 2019). A baseline crop management survey in a village is conducted to identify research priorities and establish a benchmark adoption rate for agricultural technologies. Based on survey results, the major limiting factors for sustainable crop intensification are identified, and the recommended practices are discussed with local experts and smallholders. The agreed management technologies are then implemented in a field trial. Thirty farmers are randomly selected to monitor the application of the recommended practices in the science and technology backyard village. Meanwhile, 50 fields of these farmers are selected for pilot trials on the applications of the recommended practices and tracing the changes of farmer practices. Finally, the demonstration field (100 mu) is implemented for *in situ* technology evaluation. In the demonstration field, crops are managed by the recommended practices and field days are held each month during the growing season. Farmers are informed and invited to attend these field days, where key practices for sustainable crop intensification are outlined and demonstrated in the field.

In the science and technology backyards, a variety of approaches are used to exchange and share knowledge and technologies to farmers. The first approach is demonstration. For example, in order to adapt techniques to local conditions, professionals or technicians in the science and technology backyards discuss details with farmers to establish the agreed management strategy and practices that combine farmer experience and scientific research results. These agreed management practices are used in the trial and demonstration fields, which provide the farmers with evidence-based results in order to raise awareness of the effectiveness of new knowledge and technologies. In the science and technology backyards, science-based

Photo 1. **Farmer night school in Qianya science and technology backyard. April 2020 , Quzhou county, Hebei province, China.**

© Xiaoqiang Jiao

technologies are presented on waterproof posters along main rural transportation roads and formatted in customized calendars for farmers. Meanwhile, farmers in the community and neighbouring villages are invited to visit demonstration fields on field days to read the posters, evaluate actual effectiveness of the agreed practices, and learn new knowledge and technologies.

The second approach is to train farmers. Various kinds of courses have also been designed in the science and technology backyards to train farmers in knowledge and technology transfer. Tailored training courses such as farmer morning school, farmer night school and information and communication technology (ICT) training courses are designed and used in the science and technology backyard to train farmers according to their needs (Photo 1). Farmer field schools (FFS) are also commonly organized by professionals and technicians in the science and technology backyard to train farmers.

The third approach is to provide advisory services to farmers: science and technology backyard professionals provide on-site advice, as well as regular technology updates via cell phone messaging services such as WeChat to farmers. These ICT-based advice helps risk-averse farmers understand the benefits of new technologies and practices. With the assistance of ICT, new technologies and good practices are disseminated, the problems encountered by farmers in their own fields are communicated to the professionals on time and advice for solving those problems is provided by engaging appropriate public and private institutions.

© Hongyan Zhang

Science and technology backyard graduate student provides on-site technical advices to farmers.

In recent years, the private sector has become increasingly involved with the science and technology backyards, in conducting several activities. For example, private fertilizer companies are introduced and operate in the science and technology backyards or use them as platforms to test their products and undertake activities such as soil testing, field experiments and demonstration of formulated fertilizers. Likewise, digital agricultural companies conduct field trials and demonstrations of their new technologies and digital sensing devices in association with the science and technology backyards.

CHAPTER 3

ANALYSIS OF THE INNOVATIVE ACTIVITIES IN THE SCIENCE AND TECHNOLOGY BACKYARD

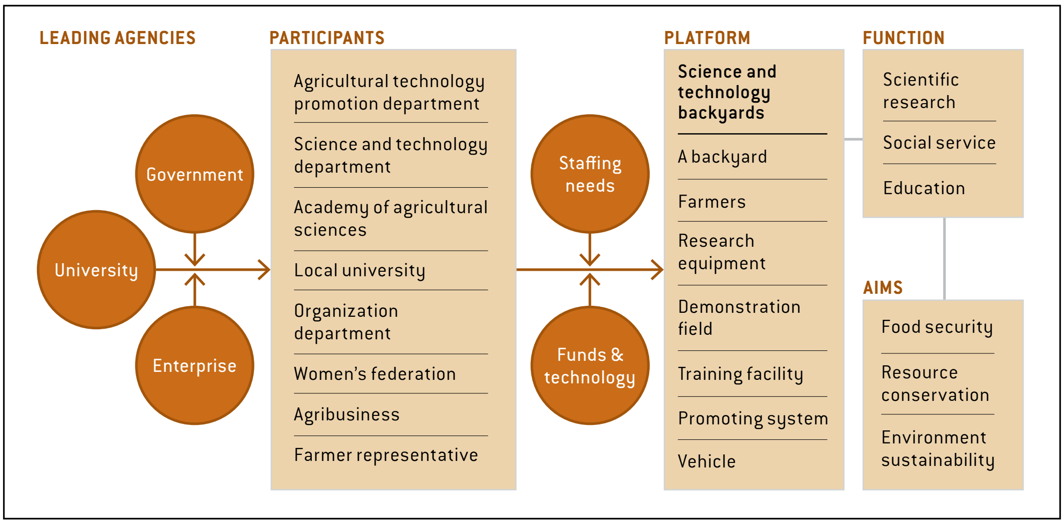
3.1. MAIN ACTORS AND THEIR ROLES IN THE SCIENCE AND TECHNOLOGY BACKYARD

As a multi-actors innovation platform, there are two important sectors in the science and technology backyard (Fig. 3). One is the public sector, including agricultural universities or institutes, research and extension agencies, science and technology management institutions, local government departments and women's federations. The other is the private sector, mainly including digital agricultural enterprises, agricultural service enterprises and agricultural inputs production enterprises (Fig.3).

(1) Farmers: From the beginning of the science and technology backyards, farmers have always played a central role. Professors, postgraduate students and all the other multi-actors of science and technology backyard worked together with, for and alongside farmers. In the science and technology backyards, the farmers are not only the major participants and the targeted recipients of knowledge and technology development and transfer, but also actual providers for the platform such as infrastructure (the backyards), on-farm research and demonstration fields.

(2) Professionals: Science and technology backyard is a kind of research-triggered innovation platform to provide new knowledge and new technologies for smallholders as they strive to achieve sustainable crop intensification. The responsibilities of professionals (professors) in the science and technology backyards is not only in agricultural technological research, but also as facilitators educating postgraduate students, farmers and technicians. There are also coordinators in most science and technology backyards, responsible for organizing and coordinating multi-actors interacting activities in this kind of multi-actors innovation platform. In the science and technology backyards, professionals provide a set of recommended solutions based on learning theory and discuss with smallholders the potential adaptive solution needed. Then the agreed solutions are implemented by smallholders. A set of field trials and demonstrations is conducted involving professionals and smallholder farmers. Based on these results, an array of products and guidelines for sustainable crop production are developed.

Figure 3. Main actors in the science and technology backyard



(3) Postgraduate students: The science and technology backyard platform is not only designed for research-triggered agricultural innovation, but is also applicable to agricultural education. Multiple tasks are undertaken by postgraduate students in the science and technology backyard. They can act as facilitators in farmer field schools (FFS), or as trainers or advisors to disseminate agricultural technologies to farmers using ICT, such as instant messaging, WeChat and apps. They also provide timely technical training to farmers in critical crop growth periods, in addition to organizing and delivering farmer training courses such as FFS and farmer night school. A further role is as researchers conducting field trials and demonstrations with smallholder farmers. Postgraduate students also help with the work of spreading and inheriting culture in this context, and are the disseminators of rural culture in rural areas.

(4) Public extension agents: Public sectors including government departments and extension agencies, relevant private enterprises and scientific education and research institutions are the major participating entities in the science and technology backyard. Public extension agencies are mandated and defined as linkages between agricultural science research and production, and a bridge to transfer research potential into practical productivity. However, the bridge does not work particularly well in many places, due to the shortage of professionals in public extension agencies, or the limited opportunities to update the knowledge and skills of extension agents. In science and technology backyard, extension agents work with the professionals and postgraduate students together, so their knowledge is updated and their capacities in participatory extension is improved through their interactions with the participating farmers, professors and postgraduate students in science and technology backyard. Extension agents working with professionals and postgraduate students are actively involved with the organization of some field activities such as field days, demonstrations, and FFS and farmer night school in the science and technology backyard.

(5) Women's federations: The function of women's federations is mainly to guide and facilitate women to empower their spirits of self-respect, self-confidence, self-reliance and self-strengthening, to improve overall capacities and achieve sustainable development (Box 1). However, it is a significant challenge for women's federations to fully understand the current life of rural women because of the lack of professional social workers in rural organizations. Rural women are making increasingly important contributions to agricultural production alongside taking care of children and elders in their families. In the science and technology backyards, women's federations are actively engaged with organizing local women's participation in literary, cultural and artistic pursuits and learning activities, and these activities have promoted improvements in the status of women, in their agricultural skills and overall capacities, and their contribution to local social cohesion.

(6) Private enterprises: Although the science and technology backyard approach is mainly implemented by professionals from agricultural universities, extension agencies and local government departments, it is well recognized as one of the best multi-actors innovation platforms for private enterprises to undertake experimental evaluation of their business innovations. For example, in 2011, Hubei Xinyangfeng Fertilizer Corporation started cooperation with the science and technology backyard in Xianggongzhuang village to improve its competitive abilities in fertilizer products. In that year, the corporation sent three specialists to work with CAU researchers and postgraduate students in the science and technology backyards, running field trials and demonstrations. They redesigned fertilizer formulations based on the results of farmer participatory field trials, and developed new products, by optimizing the original formulation of the combined fertilizer products. They also expanded their applications from cereal crops to other cash crops such as apples. Two years later, the new products proved highly successful with a 10 percent annual increase in sales volumes. Currently, there are several agriculture enterprises such as Yuntianhua Fertilizer Corporation and Guangxi Jinsui Agriculture Corporation actively involved in the implementation of science and technology backyards. Some private enterprises have even established and funded their own science and technology backyards on various crops.

Box 1

ROLE OF WOMEN'S FEDERATIONS IN SCIENCE AND TECHNOLOGY BACKYARDS

In 2013, the Quzhou county Women's Federation and the Fan Lizhuang science and technology backyard jointly launched a series of cultural activities (square dancing and literary evenings) for rural women. Through this process, women's cultural life has been greatly improved through organizing farmer training and square dancing, receiving farmer visits and other activities. A survey found that the women who participated in these science and technology backyard activities felt very happy (54 percent) or relatively happy (46 percent). This improved sense of happiness increased their enthusiasm for agricultural production and in this process, women enriched their lives, enhanced their capabilities and promoted family harmony.

3.2. MECHANISMS OF INTERACTION AND INNOVATION IN SCIENCE AND TECHNOLOGY BACKYARDS

In science and technology backyards, interactions occur through a combination of top-down and bottom-up approaches, involving the creation and sharing of knowledge and technologies to farmers as part of this unique combined approach. The main interaction mechanism and innovative practices most noticeable in science and technology backyards feature three key aspects: a research-triggered innovation process; the co-learning interactions of postgraduate students with other stakeholders; and the co-learning interactions of farmers with other stakeholders.

(1) Research-triggered innovation process: The starting point of science and technology backyards is to overcome the last-kilometer barrier of knowledge and technology transfer between research and applications, which is the major limiting factor for sustainable crop intensification for smallholder farmers. In science and technology backyards, research plays a leading role in knowledge and technology innovation and coordinating the innovation process of technology development and transfer. For the research-triggered innovation process in the science and technology backyards, a combined of bottom-up farmer participation and top-down researcher guidance approach was used to generate knowledge and technologies in the fields, on the farms and in the farming systems. This helped overcome the last-kilometer barrier of knowledge transfer by developing practical and farmer-owned knowledge and technologies (Photo 2).

Research in the science and technology backyards generally compared crop production on research plots with conventional farmer fields (Box 2). The results from the research plots demonstrated clearly that yields achieved though scientific research consistently exceeded those in the conventional farmer fields. Farmer participatory research on the identification and analysis of this production gap and other advancements drove the subsequent knowledge co-learning process of multiple actors in the science and technology backyards. The innovation of knowledge and technology was triggered by research, and the subsequent process of knowledge and technology applications was continuously supported and facilitated by on-farm participatory research and follow-up training activities (Box 3). These research activities triggered innovation that provided "zero time difference, zero cost, zero distance and zero threshold" knowledge and technology services to smallholders. It also empowered the smallholders through follow-up training activities to fulfil their potential based on scientific advancement. These attainable potentials are usually national policy planned and established Sustainable Development Goals (SDG) targets, but proved difficult to achieved using common traditional knowledge and technology transfer approaches.

Photo 2. Science and technology backyard helps farmers to overcome the last-kilometer barrier of knowledge transfer

© Hongyan Zhang

Box 2

SUSTAINABLE WHEAT PRODUCTION IN SCIENCE AND TECHNOLOGY BACKYARDS

In order to improve the sustainability of crop production by smallholder farmers, a set of field trials and demonstrations have been conducted in Wangzhuang village, Quzhou county, Hebei province. Inappropriate wheat planting density and excessive application of fertilizer nitrogen were the major limiting factors for sustainable wheat production. In order to improve wheat yield and nitrogen use efficiency, scientists discussed the potential solutions with smallholders and integrated soil-crop system management (ISSM) was developed with engagement of farmers. Then a series of outreach tools were used to disseminate these technologies. Intensive training at wheat key growth stages and winter was used to help more farmers understand and accept these technologies. With ISSM, the synthesis between wheat nitrogen demand and soil nitrogen supply in the root-zone temporally and spatially was achieved. Compared with farmer practices, chemical nitrogen use by science and technology backyard farmers has been reduced by 11 percent and wheat yield increased by 23 percent.

© Yu Guo

Science and technology backyard farmer and graduate student celebrated good harvest of grapes.

Box 3

POSTGRADUATE STUDENT CAPACITY BUILDING IN SCIENCE AND TECHNOLOGY BACKYARDS

Danling county, located in Chongqing, is a typical county with predominantly orange production. As a science and technology backyard postgraduate student from CAU, Long Quan has conducted field trials in orange production in Danling science and technology backyard over 2 years. Focused on high yield of orange production by combined Mg fertilizer with other horticulture practices to respond to customer demand. In Danling, he worked closely with enterprise, government and smallholder farmers. Through this approach, Long Quan mastered the dynamic of the orange supply chain and customer demand. Based on the requirements of orange supply chain, a set of field trials and demonstrations on sustainable orange production were conducted. This approach offered him excellent experience in conducting scientific field trials, data analysis and summary. Furthermore, guidelines and handbooks about high-yield and high-quality orange production were prepared. In addition, through training smallholder farmers, he acquired new experiences in training and sharing knowledge with smallholders. During his stay in Danling county, he was invited to give a series of presentations about sustainable orange production 10 times by Yuntianhua Group and ICT company.

Photo 3. Mr. Long Quan training farmers on sustainable orange production in Danling county. Chongqiang city, China, 2019.

© Long Quan

(2) Co-learning interactions of postgraduate students in the science and technology backyard: the postgraduate students working in the science and technology backyard are mostly between 25 and 30 years old, they were deployed to the front line of agricultural production for the whole year and so are in direct contact with farmers and the practical problems of agricultural production. They apply their theoretical knowledge to their on-farm participatory research. Through the implementation of farmer participatory knowledge and technology transfer in science and technology backyards, postgraduate students has completed their co-learning process with farmers by understanding farmers' knowledge, perceptions and attitudes, and with other stakeholders in many practical skills which cannot be learned from formal academic education (Box 4).

Special education procedures and a curriculum have been designed for CAU postgraduate students working in the science and technology backyards (Fig. 4), with the aim of empowering them as fully qualified future agricultural innovators. The curriculum includes a unique program of on-farm participatory research and AEAS in the science and technology backyards by working with farmers to conduct technology innovation and knowledge transfer. The students' theses are based on their on-farm participatory research and AEAS in the science and technology backyards and are mandatory to qualify for their degrees. After completion of their 3-year graduate studies involving their experience working with farmers in science and technology backyards, postgraduate students not only acquire systematic agricultural technology knowledge, but also a deep understanding of agriculture and farmers, and practical problem solving abilities, which cannot be achieved through normal formal education (Boxes 4 and 5).

© San Jiang

Science and technology backyard professor facilitate graduate student's study on designing on-farm research.

(3) Co-learning interactions of farmers in the science and technology backyard: Science and technology backyard is not only an agricultural technology innovation platform, but also a farmer education platform. Along with on-farm participatory research, a series of training activities are designed and delivered by science and technology backyard professionals (professors or researchers), postgraduate students, extension agents or farmer technicians to educate farmers to understand crop production ecosystems and learn new technologies and good practices. In addition to farmer field schools, other training methods are used in response to farmer needs. For example, field visits and observation, and farmer night school are integrated into the farmer training curriculum according to local conditions and practicalities. During the cropping season, science and technology backyard professionals including professors (researchers), postgraduate students and extension agents also provides advisory services (Fig. 4).

Farmer co-learning interactions occur through their participation in on-farm research, FFS, field visits and observations; with science and technology backyard professionals through farmer night school, and ICT-based advice. Co-learning interactions of farmers with other stakeholders in the science and technology backyard are crucial for knowledge and technology transfer (Box 5). Science and technology backyards empower farmers through participatory and non-formal education processes. Essentially, the science and technology backyard approach is a learner-centered, discovery process that seeks to empower farmers to solve real-world problems by encouraging them in participation, self-confidence, dialogue, joint decision-making and self-determination. The education investment through science and technology backyard has produced many outcomes that go beyond knowledge and technology transfer, such as the demonstration of farmer contribution to social and community development. Ample evidence showing the impacts of science and technology backyards on the farmer community and social developments has been obtained in China and the initiatives in African countries, which could not otherwise have been achieved through standard training approaches.

Figure 4. Special education procedures and curriculum designed for CAU postgraduate students working in science and technology backyards

1 Interview	2 Preliminary training	3 Coursework	4 Practice	5 Thesis
Under a special project of CAU master students, candidates will be selected and interviewed in April each year.	Before check in CAU, students stay in a science and technology backyard for several months to build capacity of hardship after they graduate.	Special courses will be started from September to December to build capacity of research and theory.	Research proposals to be accepted in January, and then field trails and demonstrations will be conducted over two consecutive years to build capacity in skills and knowledge transfer.	Theses will be submitted based on the results of field trails demonstrations, and training in science and technology backyard, followed by the Masters thesis defense.

Box 4

ACADEMY CAPACITY BUILDING OF POSTGRADUATE STUDENTS IN THE SCIENCE AND TECHNOLOGY BACKYARD

Cao Guoxin was one of the first batch of CAU postgraduate students in the science and technology backyard program. His research focused on empowering smallholder farmers to conduct sustainable crop production. From 2009 to 2015, he conducted intensive surveys, field trials and demonstrations, and traced smallholder practices over six consecutive years. During his postgraduate studies, he developed a systematic approach to conduct field trials and demonstrations in farmers' fields, and developed an approach involving scientists and farmers in knowledge transfer. With this intensive training over 6 years, he has amassed substantial experience in conducting scientific research in rural areas and the provision of systematic solutions for crop production. Most notably, the outcome of his research was reported by Nature in 2016.

Box 5

SMALLHOLDER CAPACITY BUILDING IN SCIENCE AND TECHNOLOGY BACKYARD

Hao Shuang is a maize farmer from the Northeast Plain. He is very keen to learn more advanced technologies in crop production and take part in science and technology backyard activities. Under the influence of science and technology backyard, he has established his own cooperative union adopting recommend technologies from the science and technology backyard. For example, soil testing and fertilizer recommendation and convention tillage were widely adopted in his own cooperative. Compared with common farmer practice, maize yield increased by 10 percent and economic benefits increased by 20 percent due to effective organization and technology adoption.

Science and technology backyard graduate student is discussing with farmer on soil health.

3.3. ENABLING ENVIRONMENTS

During the establishment and implementation of science and technology backyards, enabling environments are basic precursors for a successful transition towards an innovative approach in response to smallholders' practical needs and constraints. It is crucial for government and institution commitments to support the following four aspects: (1) evaluating research and education achievements should not simply be academic, but also prioritize the needs of farmers; (2) building capacities for participatory education, research and extension approaches for staff at all levels across all sectors, with adequate funding and clear regulatory principles; (3) channeling public funds for education, research and extension through farmers or farmer organizations, ensuring education, research and extension services are driven by the needs of farmers; and (4) encouraging private sector engagement in the development of science and technology backyards, and where possible, building ownership of science and technology backyards by all stakeholders.

The success of science and technology backyards requires enabling environments, including supportive policies and institutions. With the support of the Chinese ministries of education, science and technologies, and agriculture and rural affairs, CAU has established a set of clear mandatory standards or criteria for encouraging professors, researchers and postgraduate students to do more farmer-focused research and provide advisory services, and develop an incentive scheme for these participants to work on technology transfer by addressing farmer needs and solving real problems. For example, CAU places more than 30 undergraduate students in the science and technology backyard project each year. The CAU President has visited science and technology backyard students in rural area many times, particularly at key stages since 2012. The Ministry of Education has developed an alliance of the science and technology backyards in China to integrate more resources from universities and institutes. The Ministry of Agriculture and Rural Affairs has established an alliance of industries to encourage science and technology backyard to support a sustainable supply chain.

The implementation of science and technology backyards needs strong support from local government, public extension agencies, private sectors and farmer communities, involving the active participation of all local stakeholders, coordination between different sectors and sustainable funding mechanisms to support joint action on agricultural innovation. For example, in order to improve transfer of deep tillage technology, the Quzhou county government deployed 20 additional employees to work across the entire county in 2012 and provided farmers with 70 CNY per mu as subsidies for adopting the technology (Zhang *et al.*, 2016). The government additionally backs brokerage services that help farmers collaborate with researchers on their own terms. Some cooperatives focusing on deep tillage have been developed with the support of government and researchers (Shen *et al.,* 2013). Extension agents from the agricultural sections of Quzhou county have also established a solid relationship with science and technology backyard postgraduate students. When the science and technology backyard postgraduate students worked in fields, they provided technical support for them and acted as their co-supervisors.


中国农业

CHAPTER 4

IMPLICATIONS OF SCIENCE AND TECHNOLOGY BACKYARD FOR AGRICULTURAL KNOWLEDGE AND TECHNOLOGY TRANSFER AND INNOVATION

Support for agricultural education and research systems is necessary but not sufficient to develop the capacities for facilitating agricultural knowledge and technology transfer and innovation. Knowledge created by research is a fundamental for technology transfer and innovation, however, agricultural technology transfer and innovation in farmer communities cannot occur effectively without their effective linkages and interactions between research, education and extension systems. The science and technology backyard is a kind of multi-actors innovation platform which establishes effective linkages and interactions between research, education and extension. In order to successfully implement and institutionalize science and technology backyard, or similar platforms, public and private support for and investment in agricultural research, education and application systems should be encouraged and take the following aspects into consideration.

4.1. AGRICULTURAL EDUCATION

Sustainable agricultural development and innovation need future professionals with new skills and knowledge. Agricultural education designed to foster future professionals should develop an adaptable paradigm to meet new challenges. The experience of postgraduate students working in the science and technology backyards is that their technical expertise needs to be complemented by practical skills in application to their research in the implementation of development-related projects and initiatives, and this is necessary for the dissemination of good agricultural practices and innovative approaches to engage with local communities. The CAU postgraduate students who graduated after working in science and technology backyards have developed many practical skills (Zhang *et al.,* 2013; Jiao *et al.*, 2019). The implication is that both public and private sectors should invest in agricultural education to modernize curricula and courses, and the modernized curricula should be able to enhance capacity development, and to develop the practical skills of students, such as networking, coaching, facilitating, advocacy communication, leadership, teamwork and entrepreneurship skills.

On the left page: Co-learning of science and technology backyard graduate student and farmers on evaluating maize yields in trial fields.

Investment in the agricultural education systems should be shifted to enhance visibility and relevance of academic communities towards strengthening knowledge transfer and co-learning approaches to improve sustainable rural livelihoods among professors, students, farmers and other stakeholders, including local farmer organizations, traders, extension agents, rural community leaders and others.

4.2. AGRICULTURAL RESEARCH

Research is essential to trigger agricultural innovation in most cases, including sustainable crop intensification, but supporting only the research system, or isolating it from other stakeholders, will not lead to effective agricultural innovation. The science and technology backyards have demonstrated that investment in and support for research should emphasize not only research outcomes but also its interactions with extension and farming sectors to realize sustainable development through agricultural innovation. Rather than supporting research activities in isolation, agricultural development projects should view the generation and utilization of research results as parallel processes. The lesson learned from the science and technology backyards is that public investment and private support for research should encourage agricultural scientists to be involved in promoting on-farm participatory technological innovation by working with farmers and extension agents, and one potential and effective way to achieve this is for research funds to be channeled through farmers or farmer organizations to ensure research is driven by farmer demand. In this case, farmers become a part of the process of technological innovation.

4.3. AGRICULTURAL EXTENSION AND ADVISORY SERVICES

Considerable attention has been paid to the public extension sectors as the key providers of advisory services in most developing countries. However, it is widely recognized that public advisory services are in gradual decline and have limited access to smallholder farmers. Current providers of advisory services include NGOs, private companies and farmer organizations, so advisory services are increasingly pluralistic. Donor support for agricultural extension encourages pluralism, and seeks effective and efficient methods for agricultural knowledge and technology transfer and innovation. The science and technology backyard embodies this kind of approach by engaging public education, research and extension sectors and private enterprises to provide pluralistic advisory services to smallholders. The science and technology backyard is a research-triggered agricultural innovation platform and merits both investment and support. Investments in such a model will be more flexible and less defined in terms of

Photo 4. Sino-Africa science and technology backyard talent training project in CAU, June 2020, Beijing, China

© Xiaoqiang Jiao

restricted numbers of extension agents and expensive infrastructure. But good governance and accountability should be clearly defined for the science and technology backyards to counterbalance the risks that are inherent in greater flexibility.

4.4. KNOWLEDGE SHARE IN AFRICA

Compared to China, agriculture in Africa faces different and sometimes greater challenges. Due to limited infrastructure, knowledge and resources, hunger is still a prevalent problem in most African countries. Although great efforts have been made by multiple sectors, the achievements leave much to be desired. The experience and practices of science and technology backyard could offer some lessons in feeding the large and growing population in Africa using sustainable crop intensification. With the support of the World Bank, Bill & Melinda Gates Foundation, Ministry of Education of China, and CAU, 34 Africa students have been recruited from eight African countries (Burkina Faso, Ethiopia, Mozambique, Nigeria, Senegal, Tanzania, Zambia and Zimbabwe) to learn, share, and transfer the science and technology backyard model to Africa in 2019 (Photo 4). It has also attracted the interest of many enterprises with a view to involvement in the project, including international Potassium and Sulfur Group and some Chinese agriculture development companies. In the project, talent trainings especially for young students have been made a top priority. With this project, it is hoped that the science and technology backyard successes can be shared and transferred to Africa to help address the local challenges faced by agricultural production and provide valuable support for accelerating agricultural transformation in Africa towards sustainable intensification.

© Hongyuan Zhang

CHAPTER 5

CONSTRAINTS AND CHALLENGES FOR ADOPTING AND SCALING-UP OF SCIENCE AND TECHNOLOGY BACKYARD

As a multi-actors innovation platform that is still in the early stages of development, many participatory research & training tools and methods currently used in the ongoing science and technology backyards are at pre-mature stages and need to further improvement if they are to become more simple, practical, economic, effective and efficient in tune with farmers' current circumstances and needs. Quality control and standards for the monitoring and evaluations of the science and technology backyards are not in place and must be developed as well. Currently, science and technology backyard focuses mainly on agricultural knowledge and technology transfer. Broader social and economic issues such as the empowerment of smallholder farmers through marketing organizational skills, natural resource management skills and climate adaption capacities are yet to be incorporated systematically in the science and technology backyards. Social equalities, especially with adequate participation of women and youth should be enhanced further to ensure appropriate levels of involvement in the science and technology backyards. In addition to this case study, it is necessary to take further concrete steps to document more experiences and information in order to facilitate the development of quality control standards for establishing and operating science and technology backyards, including the necessary budget, basic infrastructure, and appropriate numbers of professionals and enabling policies.

Current challenges faced in the process of adoption & scaling-up of the science and technology backyards are mainly policy and institutional. In most countries, the evaluation of agricultural education and research excellence is based on academic achievements, and takes little account of farmers' demands and local agricultural development goals. Educationists and researchers in universities and research institutions have little incentive or motivation to serve farmers and farmers' communities directly. Mobilizations of educationists, postgraduate & graduate students and researchers to farmers' communities and directly work with farmers on knowledge generation and technology transfer are not easily accepted and implemented. Furthermore, the systematic separation of education, research, extension and actual farming systems in most developing countries represent the main institutional barriers to be overcome in the process of adopting

On the left page: the graduate students in science and technology backyard are inspecting maize cob in trial fields (2020).

© Hongyan Zhang

Close ceremony and farmers field day of one science and technology backyard in Quzhou city of Hebei province in China in 2019.

and scaling up of the science and technology backyards. The lack of driving forces among the separate institutional systems for facilitating interactions among multiple stakeholders must be addressed if we are to support agricultural innovations and accountabilities for empowering smallholder farmers, to achieve economic, environmental and social gains sustainably from agricultural science and technology education & research advancements.

In order to adopt and scale up the science and technology backyards, government must review current agricultural education, research and extension policies, and develop a framework of agricultural policy reform to enhance linkages between education, research and extension, and create policies and mechanisms to more explicitly promote policies on the enhancements of linkages between education, research, extension and farmers. This can be done through setting clear mandatory standards or criteria for educationists, more demand-driven researchers and extension agents, and establishing incentive schemes for educationists, researchers and extension agents in addressing farmers' demands, needs and agricultural problem solutions. Coordination mechanisms between agricultural education, research and extension need to be set up to overcome the institutional barriers to adopting and scaling up the science and technology backyards: in many countries agricultural education falls under the Ministry of Education, while extension is managed by the Ministry of Agriculture and research by the Ministry of Science and Technology. This makes interactions and communications between them much more cumbersome and difficult. Working mechanisms composed of multiple actors from diverse stakeholders should be created and maintained to establish the linkages among them. It is also important to encourage the active participation of other key actors from private sectors, NGOs, civil society, and farmers or representatives of farmers' organizations in the process of adopting and scaling up the science and technology backyards.

KEY REFERENCES

Chen, X., Cui, Z., Fan, M., Vitousek, P., Zhao, M., Ma, W., Wang, Z., Zhang, W., Yan, X., Yang, J., Deng, X., Gao, Q., Zhang, Q., Guo, S., Ren, J., Li, S., Ye, Y., Wang, Z., Huang, J., Tang, Q., Sun, Y., Peng, X., Zhang, J., He, M., Zhu, Y., Xue, J., Wang, G., Wu, L., An, N., Wu, L., Ma, L., Zhang W. & Zhang, F. 2014. Producing more grain with lower environmental costs. *Nature*, 514, 486-489.

Jiao, X., Zhang, H., Ma, W., Wang, C., Li, X. & Zhang, F. 2019. Science and technology backyards: a novel approach to empower smallholder farmers for sustainable intensification of agriculture in China. *Journal of Integrative Agriculture*, 18, 2-11.

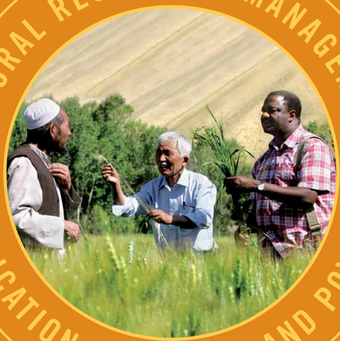
Shen, J., Cui, Z., Miao, Y., Mi, G., Zhang, H., Fan, M., Zhang, C., Jiang, R., Zhang, W., Li, H., Chen, X., Li, X. & Zhang, F. 2013. *Transforming agriculture in China: from solely high yield to both high yield and high resource use efficiency.* Global Food Security, 2, 1-8.

Tilman, D., Balzer, C., Hill, J. & Befort, B. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Science of the United States of America,* 108, 20260–20264.

Zhang, F., Chen, X. & Vitousek, P. 2013. Chinese agriculture: an experiment for the world. *Nature*, 497, 33–35.

Zhang, W., Cao, G., Li, X., Zhang, H., Wang, C., Chen, X., Cui, Z., Shen, J., Jiang, R., Mi, G., Miao Y. & Zhang, F. 2016. Closing yield gaps in China by empowering smallholder farmers. *Nature*, 537, 671-674.

Zhao, P., Cao, G., Zhao, Y., Zhang, H., Chen, X., Li, X. & Cui, Z. 2016. Training and organization programs increases maize yield and nitrogen-use efficiency in smallholder agriculture in China. *Agronomy Journal,* 108, 1944–1950.



Science and technology backyard is a kind of multi-actors innovation platform, located in rural areas, which links researchers, extension agents, private enterprises and smallholders, in order to facilitate information exchange and technological innovation in agriculture. In the science and technology backyards, agronomy professionals including researchers and postgraduate students live in the backyards of smallholder farms and work together with farmers and extension agents. Farmers are trained and knowledge is transferred through the multi-actors innovation platform, consisting of farmer field schools, participatory on-farm research, new technology demonstrations and farmer interest group or clubs. Consequently, when farmers encounter agronomy problems, they access the services of science and technology backyards without delays, limitations, extra fees or travel time. In addition, a new and effective system of technological innovation and extension is explored through involvement of university staff and students, and local extension agents in the science and technology backyards.

Office of Innovation
OINR-Chief@fao.org

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, Italy

ISBN 978-92-5-133870-4

CB2939EN/1/02.21