# Research progresses in technological innovation and integration of agricultural engineering

Zhu Ming*, Zhou Xinqun, Zhai Zhifen

(*Chinese Academy of Agricultural Engineering, Beijing 100125, China*)

**Abstract:** Based on the technical characteristics of agricultural engineering, this research developed a theoretical system and methodology on the integration of agricultural engineering technology by studying the classification of constituent technologies, technological evaluation and integration, and optimization of agricultural engineering patterns. Thirty-two integrated agricultural engineering patterns are proposed according to the methodology for different regions with different local industry backgrounds, operating scales and objects. This research provides a solid foundation for the study of the agricultural engineering technical scheme, patterns and construction standards, which can help to provide a comprehensive solution to problems relevant to modern agriculture.

**Keywords:** agricultural engineering, technology innovation, technology integration, technology classification, patterns

**DOI:** 10.3965/j.ijabe.20160906.2440

**Citation:** Zhu M, Zhou X Q, Zhai Z F. Research progresses in technological innovation and integration of agricultural engineering. Int J Agric & Biol Eng, 2016; 9(6): 1－9.

## 1 Introduction

### 1.1 Agricultural engineering and its technology

Agricultural engineering is an integrated knowledge system consisting of many technical and non-technical factors, which can include a production system or a social service system being constructed for large-scale specialized and sustainable agriculture. It is the key link that transforms agricultural knowledge into the real productivity. Agricultural engineering technology is a comprehensive subject that comprehensively combines engineering, biology, information and management science, thereby constituting the three top technology back bones of modern agriculture science, along with agricultural biotechnology and agricultural management technology[1,2]. As the most important key factor of agricultural engineering, the developing level of agricultural engineering technology directly affects the construction level of agricultural engineering. In recent years, the Chinese Communist Party Central Committee devoted much attention and investment toward the construction of agricultural infrastructure, which in turn promotes the innovation strength and achievements in agricultural engineering. But it is worth noticing that big differences in innovation, R&D investment and construction effects of agricultural engineering among the different districts, sectors and specialty fields in China still exist. In comparison with developed countries, a gap characterized by an insufficient supply of agricultural engineering technologies, low levels of assembly equipment, weak infrastructure built on a small scale, being fragmented, disordered and repeated, remains to be covered. Therefore, it is crucial to carry out agricultural engineering technology research into key technologies, construction patterns and standards, because the results can promote the construction and efficient operation of

**Received date:** 2016-05-20 **Accepted date:** 2016-10-20

**Biographies: Zhou Xinqun**, PhD, Professor, research interests: agricultural engineering, Email: 704080474@qq.com; **Zhai Zhifen**, PhD, research interests: agricultural technology application, Email: zhaizhifen0821@163.com.

***Corresponding author: Zhu Ming**, Professor, research interests: agricultural products processing engineering. Mailing address: No.41, Maizidian Street, Chaoyang District, Beijing 100125, China. Tel/Fax:+86-10-65005873, Email: mingzhu@agri.gov.cn.

agricultural engineering systems and provide general engineering and technological support for the development and modernization of Chinese agriculture[3].

### 1.2 Integration of engineeringand technology

Integration is the process of blending or uniting two or more elements into an organic functioning whole, and the core idea is a synergistic unification in a manner that solves complex system problems and improves the function of the entire system[4-6]. Any engineering project, regardless of size, constitutes an entire series of technologies that relate to each other for a designed goal[7]. The relationship between technology and engineering can be understood as elements (the former) and system (the latter). An agricultural engineering project must consist of the application and integration of multi-subject technologies and technological groups[8-10]. In addition, agricultural engineering involves constraints within multiple-body organizations and their external environment. The resource mobilization and reasonable matching need to be carefully and systematically planned, taking into account the economic, social and environmental benefits[11]. Thus, the systemic essence of agricultural engineering relates it to integration inseparably. To achieve improvement in agricultural engineering, the integration process must be studied. A study of agricultural engineering technology integration must focus comprehensively on the overall objectives of the engineering project, organically integrate the technical elements that influence consideration of the organization, the environment and other factors, so as to fully realize the complementary advantage and greatly enhance the overall effect of the system.

Although there has been a large amount of technological integration practice in agricultural engineering, most of the literature is limited to research on pure technology patterns, organizational modes or dependence on practical experience, with less consideration of social or environmental factors. There is a lack of systematic and comprehensive research on such integrationas well as a lack of scientific theory and methodology which has already been established for a systemic integration of agricultural engineering. Therefore, based on this view of system theory, the existing research focuses on the formation of an integrated route incorporating agricultural engineering technology and a methodical system, by studying the technical, organizational and social-environmental factors encompassing the study of agricultural engineering technology integration. This methodology can enrich and develop system engineering theory.

## 2 Integration stages

Academician Yin Ruiyu[12] pointed out that the engineering technology integration is divided into two stages. The first is at a technical elements level, called the assessment and integration phase, where multiple disciplines and technologies are integrated by selection, organization and optimization on a larger-scale amount. The second stage encompasses an optimization of the engineering technology pattern phase, where in the technical elements are comprehensively optimized within certain economic, social, management and other boundary conditions.

### 2.1 Technology assessment and integration

Integration at the technical elements stage involves screening the appropriate technical sources to provide feasible technical solutions. The technical sources can be divided into different types in order to cover as many resources as possible. The structure-function analysis method can be used to establish the classification clusters within agricultural engineering technology according to different status, roles and relationship among the respective technologies. Such classification constitutes the effective beginning of technology integration.

In this integrative process, a very important step is an evaluation of the possible technologies, so as to make a reasonable choice. Technology evaluation includes an assessment of advances, reliability, economical efficiency and assembility[13]. An integrated scheme of engineering technology can thus be formed after evaluation and optimization of the relevant technologies.

### 2.2 Optimization of engineering patterns

Organizations (such as investment or operational) and environments (such as economy, society or industrial) are both supportive and restrictive conditions for agricultural engineering. Any technical integration scheme has limitations, and each technical scheme can adapt to only certain conditions. Hence, it is not only a variety of technologies but also various organizations (such as enterprises, cooperatives, and farmers) and environmental factors that are involved in the engineering technology integration process.

Therefore, on the basis of the first phase in technological integration, a system for evaluation and optimization should be built by combining technical, economic, social and environmental evaluations with quantitative and qualitative analytical methods. Then the integration patterns can be derived by the merging of technology, organizations and environmental conditions suitable for specific conditions and scales.

The technical root is shown in Figure 1.

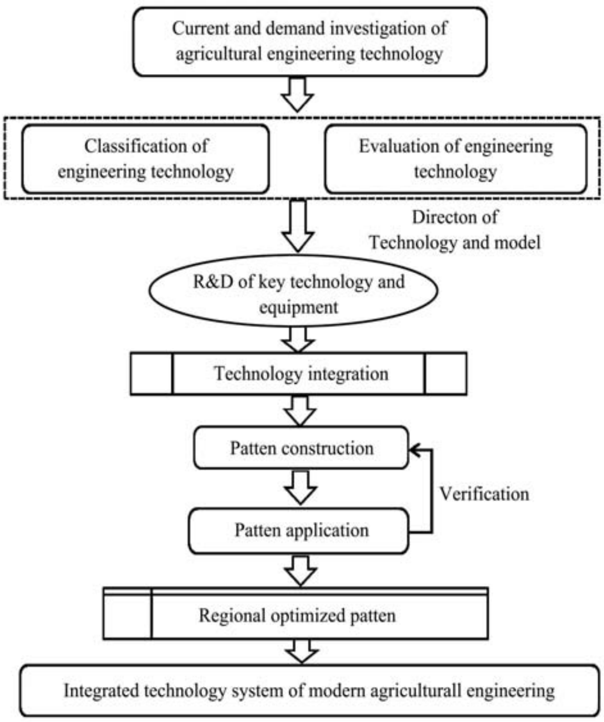


Figure 1 Technical route

## 3 Technology classification

Technology classification research can reveal a panorama of technology systems and their typical characteristics, internal structure and mutual relationships, which in turn can provide resources for the integration of agricultural engineering technology.

### 3.1 Methodology

The linear classification method classifies objects into several levels of categories according to selected attributes or features, and assorts them into a hierarchical system, expanding step by step (GB/T7027-2002)[14]. This method is a traditional one, which has the advantages of a clear hierarchy, and can fully reflect the logical relationships of different categories. It both conforms to the tradition of manual information processing and is easily computer-processed. In order to reveal the structure and function of agricultural engineering technology systems concisely, the linear classification method is used for its longitudinal hierarchy, which classifies according to the selected number of attributes or features into the corresponding number of levels of categories, then assorts them into a hierarchical, gradually expanding classification system.

### 3.2 Classification system

Because of the integrity and intersection of engineering technology, there will be too much overlap and difficulty in reflecting on the purpose of the technology if classification is implemented according to its technical attributes and forms. Therefore, it is more reasonable to consider the full functionality of agricultural engineering technology as the fundamental basis for classification, thereby using the basic idea of integrating the technology and industrial chains with technology encompassing the entire production process to guide the classification. In accordance with the linear classification method, the research reveals four classification-cataloging levels within agricultural engineering technology, namely, major, mid-level, minor classes and subclasses, encompassing the engineering technology chain, technical links, technical functions and technical measures, respectively[15]. The hierarchical relationship is illustrated in Figure 2.

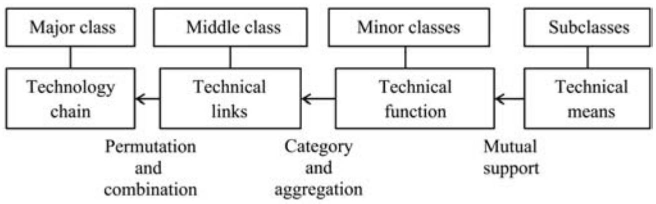


Figure 2 Hierarchical relationship of technology classification

### 3.3 Classification results

In accordance with the main areas of agricultural production before, during and after, this study divided the agricultural engineering technology system into seven major classes: farmland infrastructure, mechanization, facilities, processing and storage of products, logistics, environmental protection and information (Figure 3), and gradually subdivided into 39 mid-level classes, 151 minor classes, and 369 subclasses (Figure 4)[16]. The results can reflect the entirety of agricultural engineering technology in detail, construct a relatively complete system and fill the gap in agricultural engineering technology research.

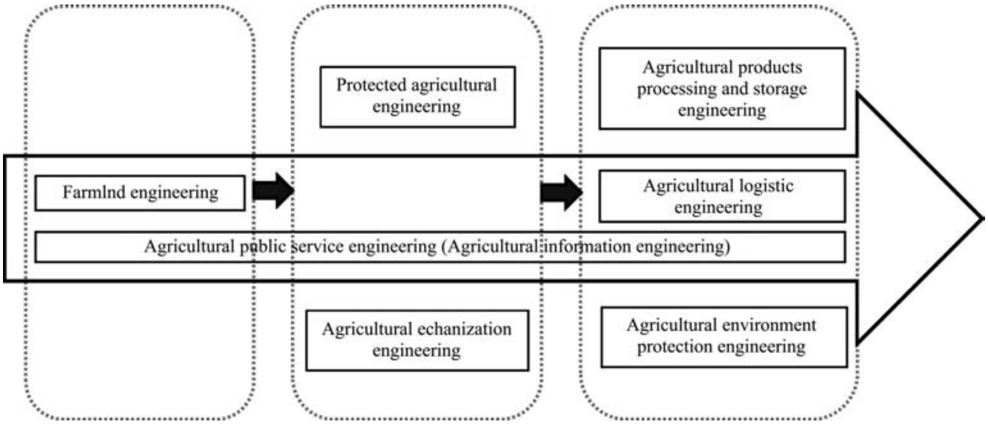


Figure 3 Major classes of agricultural engineering technology

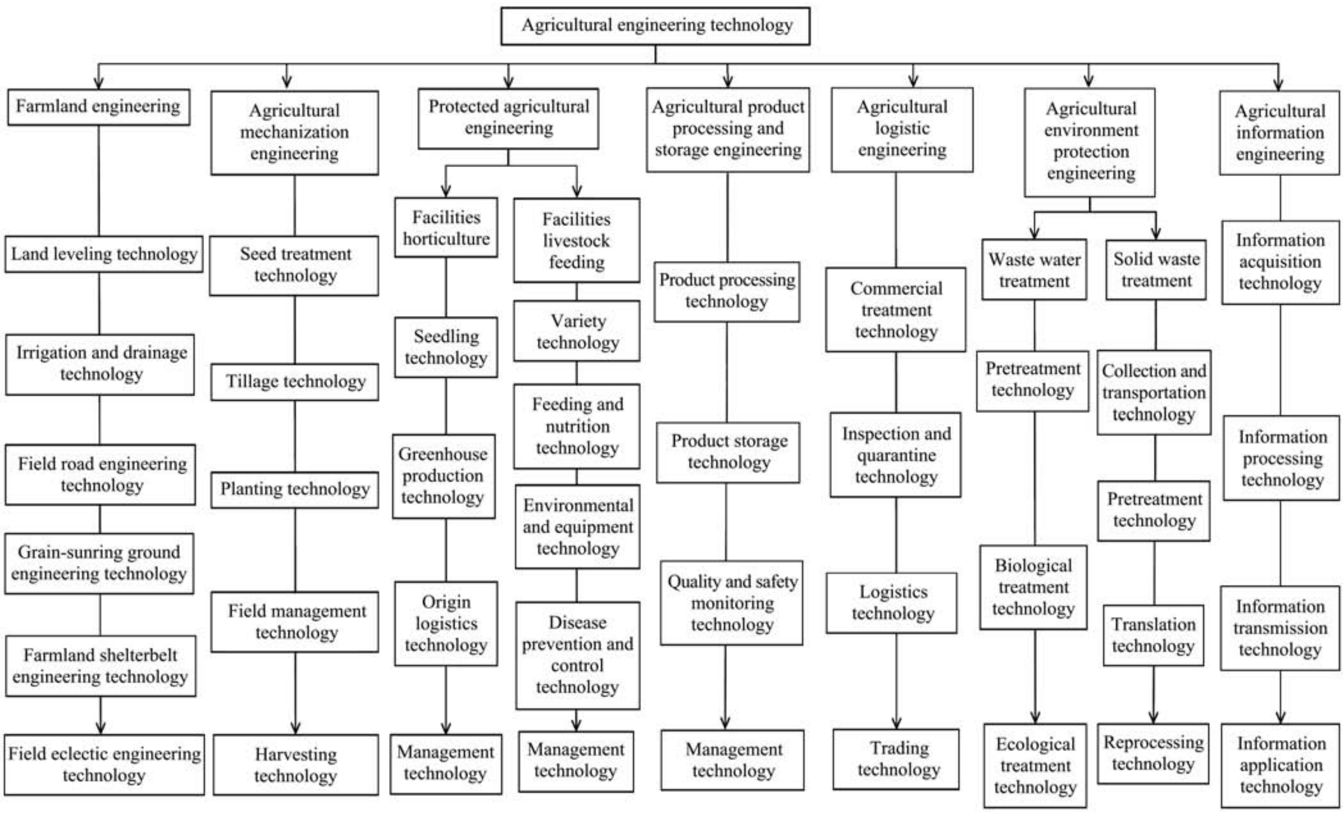


Figure 4 Middle classes of agriculture engineering technology

## 4 Technology integration

Integration is the process of combining multiple related elements into an organic functioning whole, and the core idea is synergistic unity. The fundamental goal in the integration of engineering technology is its economic effect. Because of the attraction and inducement of an economic benefit, the idea of integration can penetrate into engineering practice. In the integration process within agricultural engineering technology, a proper evaluation can ensure the best technical configuration, that is, a lower cost and greater efficiency, resulting in lower transaction costs and better economic effects[17,18].

### 4.1 Methodology

Technology integration is a systematic process encompassing input，transformation and output, in which the input consists of the technology as a whole (containing subclass, mid-level, and minor classes); output is the preferred integration program; and transformation (technology integration) is the process by which the whole forms an integrative system (or module) by matching. Integration is a systematic engineering methodology, and its general approach is to set goals, building schemes, evaluating and optimizing[19,20]. This study formulated three kinds of integration methods:

(1) Construction-Evaluation-Optimization

On the basis of technological classification, screen the whole technology from the production process and its technical aspects to constitute the preliminary, alternative integrated scheme. Then, evaluate the result to obtain a viable integration scheme based on the evaluation results as illustrated in the flow chart in Figure 5.

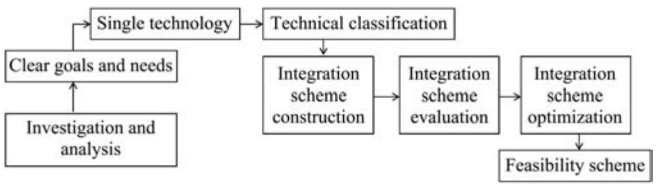


Figure 5 Flow chart of Construction-Evaluation–Optimization method

(2) Evaluation-Construction-Optimization

On the basis of technological classification, evaluate the various technologies with regard to their different aspects. According to the evaluation results, construct an alternative scheme in three levels: high, middle and low. Then combine these with production practice and expert experience to recommend a feasibility scheme in different constraints, as depicted in the flow chart in Figure 6.

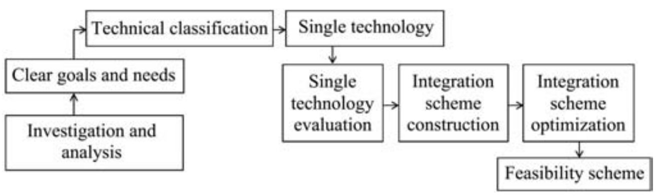


Figure 6 Flow chart of Evaluation–Construction-Optimization method

(3) Goal-Evaluation-Optimization

On the basis of technological classification, construct the best integrated scheme of agriculture engineering technology from the production perspective and technical aspects. Construct an evaluation index system for the integrated scheme, and use it to evaluate the practical version. Compare the evaluation results with the best integrated scheme; then, propose the optimized content for the practical integrated scheme, as illustrated in the flow chart in Figure 7.

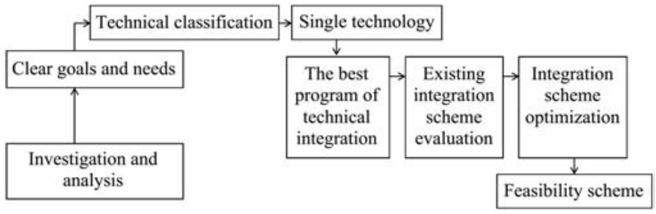


Figure 7 Flow chart of Goal-Evaluation–Optimization method

## 4.2 Technologically integrated scheme

In accordance with the concept of technology integration, this study formulated 71 feasibility schemes for agricultural engineering technology in different regions, including farmland infrastructure, mechanization, facilities, processing and storage of products as well as their circulation, environmental protection and information services. These schemes can be replicated as follows:

(1) Farmland infrastructure

Use the Goal-Evaluation-Optimization method to construct an integrated scheme for farmland infrastructure engineering of projects in plain, hilly and modern irrigation from five aspects: fields, irrigation and drainage, roads, forest protection and electrification.

(2) Mechanization

Use the Construction-Evaluation-Optimization method to resolve and compare the fully mechanized technologies, and reconstruct them in every link. Then, formulate integrated mechanical schemes for the key link and all of the fieldas well as the entire production chain.

(3) Facilities

Use the Construction-Evaluation-Optimization method to reconstruct greenhouse horticultural technologies from three aspects, including production facilities, original logistics and general management; then, formulate a technologically integrated scheme for plastic and multi-span greenhouses.

(4) Processing and storage of products

Use the Construction-Evaluation-Optimization method to formulate an integrated scheme for the processing and storage of four crops, including corn, potatoes, bananas and peanuts, from the corresponding technical links in the production flowchart.

(5) Circulation of products

Use the Evaluation-Construction-Optimization method to focus on harvesting, commercialized treatment, pre-cooling, loading and unloading, storage, transportation, trade, quality control and monitoring as well as other aspects of circulation to formulate high-, mid- and low-level integrated circulation schemes for fruits and vegetables, fresh fish and eggs.

(6) Environmental protection

Use the Construction-Evaluation-Optimization method to formulate an integrated scheme for waste recycling from two aspects: waste-water treatment and solid-waste disposal. Then, further devise schemes for the technologies addressing fertilizers, feed processing, binders and materials.

(7) Information

Use the Evaluation-Construction-Optimization method to focus on different aspects and control points for regulating the quality of agricultural products and establishing an information service. Then, formulate high-, mid- and low-level integrated schemes for monitoring the quality and safety of aquatic products and vegetables. Thus, agricultural information services can be formed.

## 5 Optimization of engineering patterns

Patterning is a methodology to solve certain classification problems emphasizing formal laws; moreover, this methodology constitutes a summary of experience to solve the problems[21]. Agricultural engineering technology patterning is a new paradigm for developing modern agricultural construction, being based on regional characteristics, possessing good economic and ecological environment benefits, as well as being easily extendable. Due to regional differences in climatic conditions, economic levels and subjects of construction and operation, such patterning is characterized by regional, phased, systematic and hierarchical diversity, as well as having no fixed pattern that can be copied[22]. Therefore, optimization of a regional pattern should be in accord with the local conditions and seek truth from facts, in order to improve the matched-degrees and collaboration of major agricultural engineering organizations, service objectives, industry types, technology and equipment. Then, appropriate technology patterns can be established for developing local economies and promoting the transformation and upgrading of agriculture.

### 5.1 Pattern construction

An agricultural engineering technology pattern comprises a whole with a specific target, function, and structure, consisting of subjective, objective, technological, organizational and environmental conditions as well as other basic elements. Based on industrial- and value-chain theories, this study proposed a systematic and complete operational method for an engineering technology system which coupled technology, organization and industry patterns. In such a system, the technology pattern is the basis of the general one; the feasible solution set is from technology integration, and the organizational mode is the manner in which the subject operates. At present, the cultivation of family farms, specialized households and peasants' cooperative organizations, as well as leading agricultural enterprises and other new management subjects are major tasks for rural reform and development, also having great vitality and potential. This study focused on the organizational pattern of new agricultural management subjects in different development scales (family farms, specialized households, specialized farmers' cooperative organizations and leading agricultural enterprises), and different developmental stages (new construction, reconstruction, expansion). After considering the regional industrial layouts, development environments supporting capacities and other factors, the industry pattern was set. The purpose of coupling patterns is to render technology, organization and industry systems with specific and ordered at a higher level, and obtains three kinds of patterns which can support each other and demonstrate a new systematic emergence that cannot be obtained in isolation. Then an integrated pattern can be formulated for different scales and developmental stages.

### 5.2 Method of pattern optimization

Pattern optimization is a feasibility analysis process based on pattern construction and decision-making.

Based on technology integration, pattern optimization of agricultural engineering technology implements holistic research concerning integration schemes, operating-services subjects, socio-economic developments and environmental sustainability, which consist of four stages: construction, evaluation, demonstration and optimization, as illustrated in Figure 8. This study proposed patterns for different regions, subjects, industries and scales, all of which encourage the components of agricultural engineering to achieve the best economic, social and ecological benefits in design, project construction and allocation of resources.

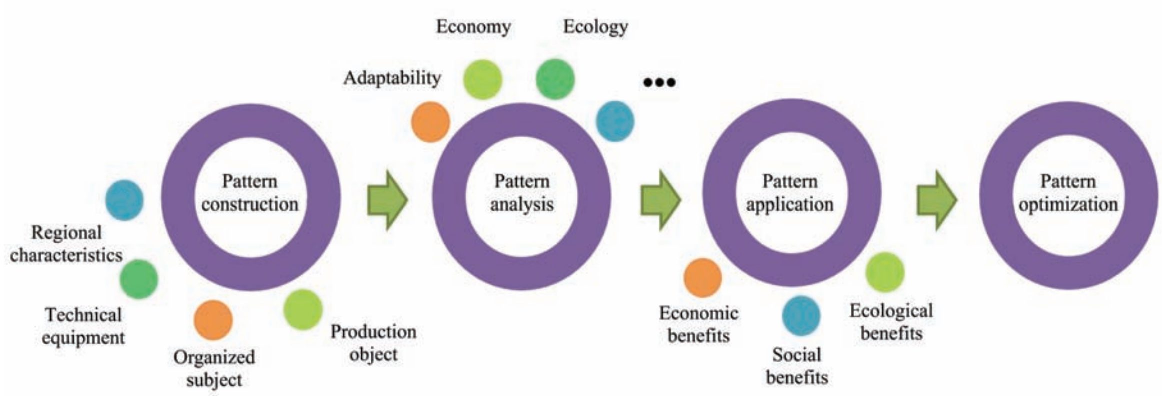


Figure 8 Flow chart of pattern optimization of agricultural engineering technology

### 5.3 Pattern evaluation

Evaluation of pattern optimization is a decision-making process. Because the complex giant systems characteristic of agricultural engineering technology patterns encompass vast areas, complex operating subjects, vast related content and strong comprehensives, it is imperative to establish an evaluation system in order to examine the effects, as well as promote the improvement and development of the patterns. Many factors are involved in the problem of comprehensive evaluation of complex systems: technological, economic, social, environmental and other factors must be comprehensively considered, all of which can render uncertainty, randomness and fuzziness in the process. Hence, it is difficult to use a rigorous and accurate evaluation method. At present, such methods rely mainly on qualitative and quantitative approaches, objective states and subjective descriptions, such as analytic hierarchies, fuzzy comprehensive evaluations, as well as multi-attribute and multi-objective decision-making methods. The Analytic Hierarchy Process (AHP) is a decision-making method, which first resolves the elements related to a decision into objectives, standards and indices, followed by qualitative and quantitative analysis. By using AHP, this study analyzed and integrated all types of elements impacting the pattern. Therefore, the evaluation system for an integrated pattern was divided into objective, standards and index layers, in which the entire index is a system and each standards levels a complete subsystem. After determining the index system, the Delphi method was used to measure the weight of every standard-to-objective and every index-to-standards.

### 5.4 Typical optimization patterns

Based on technological classification and integration, focusing on the needs of economic, social and natural conditions in different regions and various operational subjects, this study undertook systematic and integrated research in seven agricultural infrastructure and equipment engineering fields, including farmland, mechanization, protected-area, processing and storage of products, logistics environmental protection engineering and information service, and optimized 32 typical agricultural engineering patterns for verification and demonstration (Table 1)[22-26].

## 6 Results, application and discussion

(1) This research provided an advanced theoretical method for integrated innovation of agricultural science and technology. Original and integrated innovations, as well as re-innovation after introduction and absorption, are the three major areas of technological innovation.

**Table 1 Summary of agricultural engineering technical patterns**

| No. | Pattern name | |
|---|---|---|
| 1 | Construction pattern for paddy mono-cropping system in Northeast China plain | |
| 2 | Construction pattern for paddy double-cropping system in North China plain | |
| 3 | Farmland optimization pattern for arid areas of Northwest China | |
| 4 | Integration pattern for modern irrigation engineering technology | |
| 5 | Complete mechanization pattern for corn production in large cooperatives | |
| 6 | Complete field mechanizationpattern forwheat/corn in medium-sizecooperatives | |
| 7 | Complete mechanizationpattern forwheat/corn in medium-sizecooperatives | |
| 8 | Complete mechanization pattern forwheat/corn in large enterprises | |
| 9 | Field-key-linkmechanization pattern forrice/wheatin large cooperatives | |
| 10 | Field-key-link mechanization pattern for rice/Cornin medium cooperatives | |
| 11 | Field-key-link mechanization pattern for rice/wheat in small cooperatives | |
| 12 | Field-key-link mechanization pattern for rice in small cooperatives | |
| 13 | Conservation tillage pattern | Ridge culture for mono-cropping of maize in Northeast China |
| | | Mono-cropping of wheat in Loess Plateau |
| | | Double-cropping of wheat and corn in North China |
| 14 | Vegetable production pattern for greenhouse at cooperative in Northwest China | |
| 15 | Greenhouse automation pattern for flower production atenterprise in North China | |
| 16 | Barn-healthy feeding patternforpig farm in Southwest China | |
| 17 | Point-of-origin processing and storage pattern for peanuts | |
| 18 | Point-of-origin storage pattern forpotatoes | |
| 19 | Origin processing pattern of corn | |
| 20 | Point-of-origin commercialized processing pattern for bananas | |
| 21 | Farmland-market pattern for winter vegetables in Southern China | |
| 22 | Company +Farmers circulationpatternforeggs | |
| 23 | Circulationpattern forfamous live freshwater fish in southeast coastal area | |
| 24 | Circulation pattern forfreshwater fish in Yangtze Basin | |
| 25 | Circulation patternforpomelos in Zhejiang, Fujian and Guangdong | |
| 26 | Environmental protection pattern for non-profit agricultural production | |
| 27 | Environmental protection pattern for inside-circle marketing | |
| 28 | Environmental protection pattern for semi-non-profit outside-circle production | |
| 29 | Agricultural information service pattern | |
| 30 | Quality and safety testing laboratory construction pattern for agricultural product | |
| 31 | Information technology integration pattern for quality and safety supervision of aquatic product | |
| 32 | Information technology integration pattern for quality and safety supervision of vegetable | |

However, integrated innovation lacked supportive scientific and systematic theory, especially for agricultural science and technology innovation, which constitutes a complex system involving biotechnology as well as engineering and information technologies plus other disciplines, all of which are used in an entire industrial chain that links planting, breeding and processing, as well as combining production, supply and sales. By using system knowledge, this study constructed a methodically integrated system of agricultural engineering technology from technical classification and integration to pattern optimization, discussing how to build, evaluate and optimize an agricultural engineering technology pattern completely and systematically. It also provided theoretical guidance for integrated innovation not only for agricultural engineering, but also for all agricultural research, thereby playing an important role in promoting an integrated innovation level for agricultural science and technology and its conversion rate.

(2) This research provided a holistic solution for constructing modern agriculture. The research content covered seven agricultural engineering fields, including farmland, mechanization, protected-area, processing and storage of products, logistics, environmental protection and agricultural information, which comprise the key technologies in the entire industrial chain of production before, during and after. Our research results can provide a roadmap of technical standards and construction programs for agricultural engineering in various typical regions, industries and operators' subjects, which constitutes a comprehensive and systematic solution for agricultural engineering technology in the blending of agricultural machinery and agronomy, the promotion of good farmlands, good seeds and manners, as well as the coordination of production, living and ecology during an adjustment in agriculturalproduction.

(3) This research formulated 32 integrated optimization patternsin seven agricultural engineering fields and has achieved good results in their practical application. However, these integration patterns are limited to their individual fields, respectively. The more comprehensive integrated patterns, which cover the entire industrial chain for the production of certain crops, need further exploration. Management information systems which can provide agricultural engineering technology queries, optimization patterns, and project performance evaluations should be developed in the future to further support the main food crops of China.

## [References]

[1] Zhu M. The Integration Theory and Method of Agricultural Engineering Technology. Beijing: China Agriculture Press, 2013. (in Chinese)

[2] Zhu M, Guo H, Zhou X. Implementing scheme for establishment of modern agricultural engineering system. Transactions of the CSAE, 2010; 26(1): 1–5. (in Chinese with English abstract)

[3] Qi F, Zhu M, Zhou X, Wei X. Relationship analysis between agricultural engineering and agricultural modernization in China. Transactions of the CSAE, 2015; 31(1): 1–10. (in Chinese with English abstract)

[4] Qian X. Scientific Decision and Systemic Engineering. Beijing: China Science Press, 1990; pp.1–8. (in Chinese)

[5] Jin J, Zou R. Integrated innovation andtechnology development. China Soft Science, 2002; 12: 48–51. (in Chinese with English abstract)

[6] Jiang H, Chen J. Integrated innovation: A new type of innovation. Scientific Management, 2002; 5: 31–39. (in Chinese with English abstract)

[7] Iansiti M. From physics to function: An empirical study of research and development performance in the semiconductor industry. Journal of Product Innovation Management, 1999; 16(4): 385–399.

[8] Miteham C. Thinking through technology: The Path between engineering and philosophy. The University of Chicago Press, 1994; p.19.

[9] Kroes P, Meijers A. The empirical turn in the philosophy of technology, UK: Elsever Science Ltd., 2001.

[10] Leender MAAM, Wierenga B. The effectiveness of different mechanisms for integrating marking and R&D. Journal of Product Innovation Management, 2002; 19(4): 305–317.

[11] Bueeiarelli L L. Engineering Philosophy. Delft University Press, 2003; pp.23–75.

[12] Yin R. Understanding of engineering innovation and implementation of scientific development concept. Engineering in interdisciplinary perspective (Vol. 2). Beijing: Beijing Institute of Technology Press, 2006. (in Chinese)

[13] Song C, Zhang Y, Li B. Comprehensive evaluation index system and method on resource utilization technology of agricultural residues. Transactions of the CSAE, 2011; 27(11): 289–293. (in Chinese with English abstract)

[14] GB/T 7027-2002. The principles and basic methods of information classification and coding. Chinese National Standards, 2002; 6(4): 78–83. (in Chinese)

[15] Qi F, Zhou X, Ding X, Wei X. Discussion on classification method of protected agricultural engineering technology. Transactions of the CSAE, 2012; 28(10): 1–7. (in Chinese with English abstract)

[16] Wang D, Shen J, Sun J, Liu Q, Liu L, Zhao L, et al. Engineering technology classification of processing and storage for agricultural product producing area. Transactions of the CSAE, 2013; 29(21): 257–263. (in Chinese with English abstract)

[17] Huang G, Han L, Liu X, Yang Z. Establishment of evaluation system for integrated agricultural mechanization engineeringtechnology. Transactions of the CSAE, 2012; 28(16): 74–79. (in Chinese with English abstract)

[18] Wu H, Lu D, Li H, Jin Z. The integration issues and strategies of fresh water fish circulation technology. Logistics Sci-Tech, 2012; 6: 7–12. (in Chinese with English abstract)

[19] Zhang R, Zhang X, Yang J, Yuan H. Wetland ecosystem stability evaluation by using Analytical Hierarchy Process (AHP) approach in Yinchuan Plain, China. Mathematical and Computer Modelling, 2013; 57: 366–374.

[20] Gerdsri N, Kocaoglu D F. Applying the Analytic Hierarchy Process (AHP) to build a strategic framework for technology road mapping. Mathematical and Computer Modelling, 2007; 46(7-8): 1071–1080.

[21] Qi F, Zhou X, Bao S, Ding X, Wei X, Lian Q. Expression and evaluation method of integrated modes for protected horticulture engineering. Transactions of the CSAE, 2013; 29(8): 195–202. (in Chinese with English abstract)

[22] Qi F, Zhou X, Ding X, Wei X. Constructing methods of engineering integrative mode for protected horticulture. Transactions of the CSAE, 2011; 27(8): 1–7. (in Chinese with English abstract)

[23] Huang H, Yang M, Huang G. Construction and evaluation of mechanized production engineering modefor major food crops. Transactions of the CSAE, 2013; 29(23): 53–61. (in Chinese with English abstract)

[24] Shen F, Zhang K, Yang P. Research on technology integration of agricultural wastewater treatment and regional project pattern construction. Environment and Sustainable Development, 2013; 2: 56–59. (in Chinese with English abstract)

[25] Shen Y, Zhang Y, Xiang X, Wang Y, Cheng H, Luo Y. Construction of resource utilization engineering mode for agriculturalresidues. Transactions of the CSAE, 2013; 29(11): 210–216. (in Chinese with English abstract)

[26] Zhao C, Li D, Chen Y, Li J, Ma C, Qiu J. Modern agricultural information service mode, theoryand approach of engineering integration. Guangdong Agricultural Sciences, 2013; 22: 183–187. (in Chinese with English abstract)