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The development of land engineering as an academic discipline in China: historical overview and strategic thinking

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Abstract: Land engineering is a specific new academic discipline in China. Although the undergraduate major of land engineering was officially approved and established lately since 2017, the birth of land engineering as an academic discipline dates back 40 years ago. It has passed through four development stages: the incubation stage in 1978-1985, the initial stage in 1986-1997, the growth stage in 1998-2011, and the expanding stage from 2012 to present. However, land engineering as an academic discipline remains immature and seriously lags behind practice. There are still no unified academic community and broad academic consensus. After a historical overview of the four development stages, this study gave a strategic consideration to five key questions. We argue that the study object of the discipline is land engineering activity, which is defined as the artificial transformation of a land complex combined by various natural and human elements. The uniqueness of the discipline is rooted in its ability to study the comprehensive and integrated reorganization or rebuilding of various elements of land as a complex, with the theory of land complex reconstruction being the core theory. The discipline of land engineering is based on land pure science and land technology, and is one basis of land management. It consists of two modules (rural land engineering and urban land engineering), five secondary disciplines of each module (land development, land rearrangement, land improvement, land protection, and land remediation), and more than 30 research directions. Various technologies are only instrumental but not essential components of land engineering as an academic discipline.

Keywords: land engineering; development stage; discipline uniqueness; theory system; subject matter; land science

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1. Introduction

Land is the material basis for human survival and development, but there are many problems with land in relation to human needs, such as land contamination (Pollard et al., 2004; Forton et al., 2012), land fragmentation (Dijk, 2003; Sklenicka et al., 2017), land degradation (Dregne, 2002; Bai et al., 2008; Wairiu, 2017), and land destruction (He and Su, 2002; Cheng et al., 2017). Engineering measures are often necessary to solve these problems, and all countries in the world have land engineering practices. However, unlike the universality of land engineering practice in the world, it is a relatively unique phenomenon for land engineering to consciously be considered and developed as an academic discipline[①] in China. The uniqueness of this approach in China is largely associated with the countries' special conditions, e.g., large population and relatively insufficient land, public ownership of land, centralized government, government-led land engineering practice[②], and large of land engineering projects implemented every year. Statistically from 2006 to 2012, China inspected and accepted 152.3 thousands of land consolidation projects[③], with a total investment of 220.37 billion yuan (Yang et al., 2014).

The development of land engineering as an academic discipline in China is relatively new. The proposal for land engineering to be considered an academic discipline was made after the domestic reform in 1978. In the past four decades, the discipline of land engineering has gone through extraordinary developments, and much positive progresses have been achieved. In recent years, many research papers devoted to the discipline construction of land engineering have published (Han and Zhang, 2014; Liu, 2015; Hu et al., 2017; Cheng et al., 2018), and three batches of 10 universities have been officially approved to establish the undergraduate major of land consolidation engineering (Ministry of Education, 2017, 2018, 2019). However, although the discipline of land engineering has gradually established in China, but it is not mature and seriously

① In fact, not just land engineering but the conscious development of the whole land science discipline (i.e., land survey, land ecology, land economics, land appraisal, land planning, land law, land policy, and other sub disciplines) is a relatively unique phenomenon within China.

② In China, there are more than 2000 official land engineering agencies, belonging to the land resources administrative departments of the national, provincial, municipal and county level governments.

③ The concept of "land consolidation" in China has broad implications, it includes land development, land redevelopment, land rearrangement, land reclamation, land protection and other related land engineering activities. But subject to management responsibilities and statistical limitations, land consolidation here only includes land development (refers only to land development for agriculture use), land readjustment (refers only to farmland adjustment), and land reclamation (mainly refers to rural settlements and mining land reclamation). Of the 152.3 thousands of land consolidation projects, 96.6 thousands were land development projects, 26.4 thousands were land readjustment projects, and 29.3 thousands were land reclamation projects.

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lags behind practice. According to the theory of paradigm (Kuhn, 1962), the paradigm is a necessary condition or basic mark for a mature discipline. By contrast with other mature disciplines (e.g., agricultural engineering and hydraulic engineering), the disciplinary paradigm of land engineering in China has not really been formed, and there are still no unified academic community and broad academic consensus. Against this background, a historical overview of past developments and a consideration of several strategic questions facing the future are necessary. These will not only provide important guidance for the further development of land engineering discipline in China, but will also be of significance for other locations where researches related to land engineering are conducted.

2. Historical overview of the past 40 years

Engineering is a discipline focusing on changing the world for the better and engineering needs to be understood in the context of its role in society (Lawlor, 2016). For engineering disciplines development one main rule is social demand driving. The formation process of academic community and academic consensus for engineering disciplines is largely driven by common social needs. In the past four decades in China, the development of land engineering as an academic discipline was largely driven by the social needs (especially economic growth and ecological protection) related to land. According to and marked by significant related events, the discipline development of land engineering in China can be divided into four stages.

2.1 The incubation development stage: 1978-1985

As we know, China started domestic reform in 1978, after a long period of social unrest and economic stagnation. China thus returned to the normal track of economic development. Restoring agricultural production was a top priority, and China's domestic reforms began in the countryside and agriculture. Land is the basic means of economic production, especially for agricultural production. So the practical need for land engineering was then very urgent, and land engineering related research was active subsequently, especially agricultural land engineering. It was in this context that land engineering as an academic discipline begun to gradually incubate. There were three main development points at this incubation stage.

First, a professional committee was established and two national academic symposiums were held. The National Science Congress held in March 1978 made it clear that the research and

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application of agricultural engineering should be strengthened to promote agricultural modernization. And then in November 1979, China Agricultural Engineering Society was established. Along with this, the professional committee of land development and use engineering was set up, which was later renamed as the professional committee of land use engineering. Following its establishment, the committee became an important force promoting the development of land engineering as an academic discipline in China (Yun et al., 2009). Organized by this committee in April 1983, the first national academic symposium on land use engineering was held, with a focus on the role of land use engineering, the planning of state farm, and the amelioration of saline-alkaline land in the Huang-Huai-Hai Plain (Chang, 1983). Nearly 150 people attended the symposium, and a collection of papers in two volumes was subsequently published. And then, the second national academic symposium was held in 1984 and mainly discussed the direction and tasks of the discipline development of land use engineering (Xu, 1989).

Second, several papers published to discuss the basic questions of the discipline. In August 1981, the journal of Issues in Agricultural Economics published one paper introducing land development and use engineering as an important component of agricultural engineering (Zhang, 1981). Following closely in October 1981, the journal of Agricultural Engineering published a paper providing an analysis of the origin, contents, and characteristics of land use engineering as an academic discipline in China (Xu, 1981). In July 1984, the journal of Soil and Water Conservation in China published another paper and introduced the cause and significance of land use engineering research as a sub discipline of agricultural engineering (Zhang, 1984).

Third, the practical agricultural land engineering activities were academically analyzed. Serving to agricultural modernization, various agricultural land engineering activities had been studied, including farmland fundamental construction (Xi and Xie, 1979; Xiong, 1981) , saline-alkaline land amelioration (Zhao and Wu, 1978; Zhang, 1983; Chen and Yu, 1985), land resource development (Fan et al., 1980; Wen, 1983; Xu et al., 1985),farmland and grassland improvement (Xu et al., 1985), and low and medium yield farmland transformation (Li and Guan, 1984). In addition, the control of land desertification to reduce the threat to farmland and pasture had aroused researcher's constant discussion (Zhu and Liu, 1980; Di et al., 1982; Zhu et al., 1984).

2.2 The initial development stage: 1986-1997

Economic development had led to large-scale land development and utilization. In particular,

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a lot of arable land has been occupied and destroyed. Under this background, the State Bureau of Land Administration was established in February 1986 to strengthen the national unified administration of land, especially for the protection for arable land. And in June of the same year, the Land Management Law was promulgated. Hence, land administration was separated from the agricultural sector and was strengthened by the new independent departments. This had quite promoted the practice and discipline development of land engineering. And then, the discipline of land engineering in China entered the second stage of development. At this initial development stage, there were four main developments of the discipline.

First, several specialized books were published. In December 1987, the first academic textbook named Land Use Engineering was published, which signified the formal birth of the discipline. The textbook defined the basic concept of land use engineering and elaborated the specific contents of land use engineering discipline (Xu and Chen, 1987). In May1993, the handbook of land use engineering was published by the Agricultural Press, as the second one of agricultural engineering manuals (CAERDI and BAEU, 1993). This handbook explained in detail how to scientifically carry out practical land engineering activities, such as land use survey, agricultural land evaluation, land development, land use, and land treatment. And then in 1994, the book of land use system engineering was published, and the principle and application of land use system engineering are expounded (Song et al., 1994).

Second, the research scope expanded and the research position changed. During this stage, the research scope extended to more land engineering activities (but was still largely confined to in rural areas). Those mainly were basic farmland construction and protection (Jiang, 1989; Wang and Zhao, 1995; Deng, 1997), mined land reclamation (Bian et al., 1991; Hu and Liu, 1993; Bian and Zhang, 1994), and agricultural land rearrangement (Wang, 1997; Qu et al., 1997). Meanwhile, the main research position gradually shifted from the field of agricultural engineering to the field of land science. The concept of land engineering as an important branch of land science achieved an academic consensus (Chen, 1993; Zhu, 1995; Yu, 1995).

Third, the research approaches and methods had been improved. For instances, system engineering theory and system dynamics model had been introduced and applied (Dai et al., 1991; Song et al., 1994; Liu and Zhang, 1997), project feasibility analysis, benefit evaluation and cost-benefit analysis was carried out (Yu, 1988, 1991; Mao and Hu, 1996), and principles of ecological

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design and engineering were interpreted and applied (Wang, 1990; Zhou and Zhu, 1997).

2.3 The growth development stage: 1998-2011

In March 1998, the Ministry of land and resources in China was jointly organized from the former four institutions (one of which was the state bureau of land administration), and the duties of land administration was further centralized and strengthened. In August of the same year, the amended Land Management Law was released, which explicitly encouraged land development and readjustment[①]. After that, the plans and projects of land development and readjustment were gradually on the right track and implemented more forcefully. Affected by this, the land engineering discipline in China went into the growth stage. During this stage from 1998-2011, the land engineering discipline made some positive progress, mainly in the following four areas.

First, the contents of the discipline were clearly clarified and the applied techniques enhanced a lot. As a sub discipline of land science, land engineering's core contents were considered to include land development, readjustment, reclamation, protection, treatment, and betterment engineering (Ye and Wu, 2002; Wu et al., 2007; Hu et al., 2010). And many modern technologies were applied in research, including the 3S[②] techniques (Bao et al., 2002; Chen, et al., 2007), engineering control (Fang and Yang, 2002), composite biological measures (Lv and Qin, 2003), alternative topsoil material (Li et al., 2005), soil conditioner (Wang et al.,2007; Chen and Dong, 2008; Zhang and Zhan, 2010) , tillage soil stripping (Cai,2008; Xu et al., 2011), decision support system and management information system (Liu et al., 2006; Han et al., 2007; Shan et al.,2011).

Second, the research scope and themes expanded a lot. With the development of practice in both rural and urban areas, many new types of land engineering activities were studied, such as standard farmland construction (Zhao and Hua, 2003; Liu et al., 2006; Shan et al., 2011) , ecological de-farming(Peng and Yin, 2001; Chen, 2006; Ran et al., 2010), rural residential land rearrangement (Yang et al., 2004; Yu and Sun, 2008; He et al., 2009) , hollowed village renovation(Xue, 2001; Liu et al., 2009; Zhu et al., 2010), ecological rehabilitation of mined and degraded land (Bai et al., 2000, 2001; Sun et al., 2003) , low hill and gentle slope development(Huang et al., 2009; Cao, 2011), urban village reconstruction (Li and Chang, 2002;

① Subject to the responsibilities of land administration department and unless specified in China , land development as practical term mainly refers to agricultural development of unused land, and land adjustment as practical term mainly refers to the adjustment of rural land (agriculture land and rural settlement land). Urban land development and adjustment mainly is under the jurisdiction of construction departments.

② 3S are remote sensing (RS), global positioning system (GPS), and geographic information system (GIS).

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Zhang et al., 2005;Zhang et al., 2006), "three old" reconstruction[①] (Zhou and Zheng, 2010; Yang and Yuan, 2010; Zhao, 2012), brownfield redevelopment(Cao and Guan, 2007; Guo et al., 2010, 2011) , and contaminated site remediation(Gu et al., 2008; Luo, 2011). More and diverse themes emerged in land engineering research, such as sustainable project design (Ye et al., 2002; Hu, 2005), ecological environmental impact assessment (Zhao et al., 2003; Jiang et al., 2004), social impact assessment(Yang, et al., 2006), landscape planning, design and construction (Zhang and Fu, 2005; Zhao et al., 2007; Yun and Yu, 2011), public participation (Zhang et al., 2005; Rao et al., 2007; Zhao, 2011),property rights relationship and management (Zhu and Jiang, 2003; Meng and Gao, 2008), stakeholder analysis (Zhang et al., 2006; Guo et al., 2011), ecological services evaluation (Qiao et al., 2009; Zhang et al., 2010), project performance evaluation (Jin et al., 2008; Luo et al., 2010, 2011), and strategic analysis (Chen and Han, 2004; Liu., 2011; Wu et al., 2011).

Third, several monographs and a new textbook were published. There were several monographs published as the summaries of thematic research, such as "Theory and practice of land rearrangement" (Gao, 2003), "Land reclamation theory and technology" (Zhou and Cui, 2006), "Land reclamation and ecological rehabilitation" (Hu, 2008), "Desertification and its control in Tibet" (Li et al., 2010), "Techniques and modes of degraded land consolidation in the Qinghai-Tibet Plateau" (Lv et al., 2011). And in August 2010, the second textbook named "Land use engineering science" was published (Hu et al., 2010). As one of the national planning textbooks for agricultural and forestry colleges and universities, the textbook was widely used in land related majors, especially in the major of land resources management.

Fourth, several research institutions were established. For example, the Engineering Research Center for the Ecological Restoration of Mines, supported by China University of Mining and approved by Ministry of Education, was established in June 2006, and mainly focused on the ecological restoration of mining land. Then, the Key Laboratory of Land rearrangement, jointly established by the Land rearrangement Center (part of the Ministry of Land and Resources) and China University of Geosciences (Beijing), was launched in September 2007, and mainly conducted research on land rearrangement engineering, land reclamation engineering, and land engineering evaluation. And in February 2010, the Jiangsu Provincial Land Development and

[①] "Three old" reconstruction, produced and popular in Guangdong Province, means the reconstruction of old towns, old factories, and old villages in urban.

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Readjustment Technical Engineering Center was established.

2.4 The expanding development stage: 2012 to present

With the increase of the types of land engineering activities, the phenomenon of concept confusion was prominent. In March 2012, the land rearrangement center of the Ministry of Land and Resources was renamed into the land consolidation center. From this land consolidation had become a general concept referring to various types of land engineering activities. Meanwhile, this signified that the unified management of land engineering was comprehensively enhanced. Where after, two national plans of land consolidation in five-year were implemented and vast projects were carried out. Driven by those, the discipline of land engineering in China entered into the expanding development stage, and the name of discipline changed from "land use engineering" to "land engineering". Six main developments had been made during this stage.

First, more engineering activities were studied, more themes came forth and more methods were applied. With the ecological and sustainable development of land engineering practice, the research scope had expanded to new types of land engineering activities for ecological civilization and sustainable development, such as high-standard farmland construction(Cai and Li, 2014; Fei et al., 2014; Ma et al., 2018), urban inefficient land redevelopment (Tang, 2013; Huang et al., 2014; Liu et al, 2015) , industrial land redevelopment (Feng and Tang, 2013; Luo and Wu, 2018; Gao et al., 2017, 2018), overall ecological protection and rehabilitation (Liu and Yu, 2016; Gao, et al., 2018), and green and sustainable remediation of contaminated land (Gu et al., 2015; Song et al., 2018). And with further application of diverse subject knowledge, more themes aroused the interest of land engineering researchers, such as sustainability assessment(Zhang, 2012; Zhang et al., 2014; Song et al., 2018), social assessment (Rao, 2017), farmers' willingness and satisfaction (Wang et al., 2012; Luo and Timothy, 2017), institution supply and innovation (Yang, 2012; Xiang et al., 2017), property rights rearrangement(Tian et al., 2015; He and Zhang, 2017), risk assessment and management (Liu et al., 2017; Wang et al., 2018), carbon effect accounting and analysis (Zhang et al., 2016; Zhang et al., 2018), and farmers cooperation and collective action (Zhang et al., 2018). And with the deepening of land engineering research, more research methods were applied, such as laboratory tests (Han et al., 2012), literature statistics and metrology (Yu and Bai, 2014: Wang and Zhong, 2016), structural equation model (SEM)(Wang and Nan, 2015), data envelopment analysis (DEA) (Cheng et al., 2017), game analysis (Chen et al., 2017; Gao et al.,

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2017, 2018), and emergy analysis (Liu et al., 2013; Huang et al., 2017).

Second, a large number of relevant research institutions were established, including ministerial, provincial, and enterprise institutions. Within the 46 key laboratories approved by the Ministry of Land and Resources in May 2012, there were at least six key laboratories having a core focus on land engineering science and technology. Those were the Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Key Laboratory of Redevelopment of Construction Land, the key Laboratory of Agricultural Land Quality and Monitoring, the Key Laboratory of Land Planning and Development, the Key Laboratory of Coastal Zone Development and Protection, and the Key Laboratory of Karst Ecosystem and Rocky Desertification Control. In addition to national research institutions, two representative provincial research institutions were the Gansu Provincial Engineering Research Center of Land Use and Comprehensive Consolidation approved for construction in December 2017, and the Shaanxi Provincial Key Laboratory of Land Consolidation, approved for construction in January 2018. And two representative enterprise research institutions were the Land Engineering Technology Research Institute established by the Shaanxi Provincial Land Engineering Group in March 2013, and the first research demonstration base of the mining eco-restoration industry in China established by the Xishi Eco-Technology Co., Ltd. in October 2017.

Third, the relevant research platforms and networks were created. In December 2016, the national land engineering technology innovation platform training base was established by the Land Consolidation Center of Ministry of Land and Resources and three other units. Since 2013, by hosting collaborative innovation seminars and other activities, the Land Consolidation Center has been committed to the construction of a cooperative innovation network of land consolidation science and technology. This consists of the ministerial land engineering technology innovation center, the ministerial key laboratories, the ministerial field observation and research bases, the local research stations, and the local field bases (Jiang, 2017; Li and Wang, 2017).

Fourth, a series of special textbooks, monographs, and research reports were published. The published textbooks included two editions of “Introduction to land engineering” (Han, 2013, 2017a), “Professional English for land use engineering” (Zhang et al., 2016), “Foundations of land engineering” and “Principles of land engineering” (Han, 2017b, 2017c), and “Land consolidation engineering drawing” (Qiao and Gao, 2018). Typical thematic monographs included “Theory and

practice of rural land consolidation" (Zhang and Xu, 2012), "Theory and method of mined land reclamation" (Fang et al., 2015), "Land consolidation for man-land harmonization: from theory to practice" (Yang et al., 2016), and "land reclamation techniques and methods" (Chen et al., 2018). Besides, since 2014, there had been a paper reporting the reviews and prospects of land engineering research in China published in the journal China Land Science on February or March, and there had been a research report regarding land consolidation development research in China published as blue books by the Land Consolidation Center on May or July.

Fifth, officially the occupation was recognized and the bachelor specialty was approved. In July 2015, the revised version of occupational classifications officially listed "technical personnel of land consolidation engineering" as a national occupation for the first time. It was coded as GBM20237 and defined as engineering technicians engaged in the investigation, planning, design, construction, monitoring, and supervision of land development, readjustment, and reclamation projects (Revised Working Committee, 2015). In March 2017, the Ministry of Education officially approved Chang'an University and China University of Geosciences (Beijing) to establish the bachelor specialty of "land consolidation engineering" (Ministry of Education, 2017). In March 2018, another six universities were also given permission (Ministry of Education, 2018): Hebei University of Geosciences, Hebei Agricultural University, Northeast Agricultural University, Henan Agricultural University, Gansu Agricultural University, and Yunnan Agricultural University. And in March 2019, Shenyang Agricultural University and Shanxi Agricultural University t were also given official permission (Ministry of Education, 2019).

Sixth, several theories were put forward and applied. The theory of soil reconstruction had been proposed in practical land engineering projects (Han, 2016, 2017a; Hu et al., 2017; Liu et al., 2018). The theory of spatial restructuring and land use transition was used to analyze the nature and function of land consolidation (Xiao and Ou, 2013; Long, 2013, 2014). The theory of man-land harmonization was applied to guide the practice of land engineering projects (Hong et al., 2013; Xin et al., 2015). And the theory that "mountains, waters, forests, farmlands, lakes and grasses" are the community of life and should be protected as a whole was proposed by President Xi and analyzed by scholars(Yu and Yun, 2017; Li, 2018). In addition, the theory of resilience was introduced to guide the full process of land consolidation (Zhang et al., 2018), and the theory of collaborative governance was applied in land consolidation implementation (Liu and Chen, 2016).

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Tab.1 the four development stages of land engineering discipline in the past 40 years in China

items	**the incubation stage: 1978 to 1985**	**the initial stage: 1986 to 1997**	**the growth stage: 1998 to 2011**	**the expanding stage: 2012 to present**
driving practical events	the domestic reform since 1978, the hold of National Science Congress in 1978	the establishment of State Bureau of Land Administration in1986, the promulgation of Land Management Law in1986, Regulations on Land Reclamation in 1988 and Regulations Protection of Basic Farmland in 1994	the organization of Ministry of land and resources and in1998, the twice amendments of Land Management Law in1998 and 2008, the release of National Land Development and Readjustment Plan (2001-2010) in 2003	the rename of Land Consolidation Center in 2012, the release of National Land Consolidation Plan (2011-2015) in 2012 and National Land Consolidation Plan (2016-2020) in 2017, the promulgation of Regulations on Economical and Intensive Use of Land in 2014, the official recognition of the occupation in 2015
important academic events	the establishment of the professional committee of land use engineering in 1979, two consecutive national symposiums on land use engineering held in 1983 and 1984, and so on	two national land use engineering symposiums held in 1986 and 1988, the establishment of land reclamation branch of China Land Society in 1987, two national land reclamation academic seminars held in 1987 and 1988, and so on	the establishment of land rearrangement and reclamation branch of China Land Society in 1999, the establishment of land reclamation and ecological restoration committee of China Coal Society in 2012, and so on	the consecutive forums of land reclamation and ecological restoration since 2013, two international symposiums on land reclamation and ecological restoration held in 2014 and 2017, the consecutive official approvals of the bachelor specialty of land consolidation engineering since 2017, and so on
research scope	farmland fundamental construction, saline-alkaline land treatment and amelioration, low and medium yield farmland transformation, land resource development, farmland and grassland improvement, land desertification control	outside of the left: basic farmland construction and protection, mined land reclamation, agricultural land rearrangement	outside of the left: standard farmland construction, ecological de-farming, rural residential land rearrangement, hollowed village renovation, land ecological rehabilitation, low hill and gentle slope development, urban village reconstruction, “three old” reconstruction, brownfield redevelopment, contaminated site remediation	outside of the left: high-standard farmland construction, urban inefficient land redevelopment, industrial land redevelopment, overall ecological protection and rehabilitation, green and sustainable remediation of contaminated land

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items	the incubation stage: 1978 to 1985	the initial stage: 1986 to 1997	the growth stage: 1998 to 2011	the expanding stage: 2012 to present
research themes	theoretical concept and basic contents, discipline tasks and characteristics, practical history and technological progress, and so on	outside of the left: discipline contents and position, engineering measures and techniques, feasibility analysis, benefit evaluation and cost-benefit analysis, ecological design, ecological engineering, and so on	outside of the left: sustainable project design, ecological environmental impact assessment, social impact assessment, landscape design and construction, public participation, property rights relationship and management, stakeholder analysis, ecological services values, project performance, strategic analysis, and so on	outside of the left: sustainability appraisal, farmers' willingness and satisfaction, institution supply and innovation, carbon effect accounting and analysis, farmers cooperation and collective action, risk assessment and management, property rights reconstruction, and so on
related theories	edaphology, agrobiology, ecology, and so on	outside of the left: system dynamics, systems engineering, ecological engineering	outside of the left: sustainable development, restoration ecology, landscape ecology, engineering control, soil reconstruction, property rights, ecological services	outside of the left: soil organic reconstruction, spatial restructuring and land use transition, man-land relationship harmonization, life community, resilience, land complex, collaborative governance
research methods	empirical induction, survey and mapping, comparative analysis, field test, and so on	outside of the left: comprehensive evaluation index, cost-benefit analysis, SD model, and so on	outside of the left: 3S techniques, information system, laboratory test, social survey, case analysis, and so on	outside of the left: literature statistics and metrology, SEM, DEA, social assessment game analysis, emergy analysis, and so on
published literatures	several academic papers	the first textbook and several specialized books, more academic papers	several monographs, a new textbook, more academic papers	a series of special textbooks, monographs, and research reports, more academic papers
subject status	a sub discipline of agricultural engineering	an important branch of land science	an important branch of land science, several independent courses	a main branch of land science, an approved bachelor specialty

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3. Five key strategic questions for further consideration

The discipline of land engineering has gradually established in China through the four stages, but there are still no unified academic community and broad academic consensus, reflected in concepts ambiguity and confusion, unsystematic and inconsonant contents, weak and imperfect theories, and so on. The discipline of land engineering is still in the pre- or quasi-paradigm stage. To promote its development, the following five key strategic questions need to be addressed.

3.1 Study object of the discipline

Each discipline has a specific study object, but what is the study object of the discipline of land engineering? There were two answers to this question. One answer was various types of problematic land or land problems (Hu et al., 2017; Han, 2013, 2017a). Here the problematic land mainly includes unused land, unreasonably used land, destructed land, degraded land, and polluted land (Hu et al., 2017). And land problems mainly are insufficient quantity and inferior quality of farmland, inefficient and extensive use of construction land, land pollution and destroy, and under productivity of land (Han, 2013, 2017a). Another answer was land engineering project (Wu et al., 2007; Hu et al., 2010), which has clear area and time, objectives and goals, contents and measures, investment budget and capital guarantee, and so on.

However, the both answers are inaccurate. The first answer is wrong with regarding the practical object of land engineering activities also being the study object of land engineering discipline. The real study object of the discipline should be land engineering activity itself. The second answer is wrong with limiting land engineering activity to land engineering project. In fact, land engineering project is only one operating form of land engineering activity. We argue that land engineering activity is the study object of land engineering discipline. The significance of this answer should be based on an accurate conceptual understanding of land engineering. Existing definitions of land engineering, such as the total of the engineering technical measures applied to problematic land (Hu et al., 2010) or the process of using engineering measures to solve land problems (Han, 2013, 2017a), are also not accurate and profound enough. They only provided a superficial and non-substantive conceptual understanding of land engineering.

So, what is the scientific definition of land engineering? This should be based on the correct understanding of land and engineering. To be specific, land is a complex (or synthesis) combined

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by various natural and human elements[①] (so land complex can be broken into natural complex and human complex), and influenced by various natural and human factors[②]. The concept of a complex is the scientific core of the concept of land, and comprehensiveness, materiality, spatiality, and dynamism are the basic properties of a land complex (Wang et al., 2017). Engineering is the application of science and technology to ensure the optimum conversion of natural resources for human use, and the words engine and ingenious are derived from the same Latin root, *ingenerare*, which means "to create" (Smith, 2018) . The goal and characteristic of engineering is to create a new existence for meeting human needs, while science is to reflect the existing and technology is to find ways to change the existing (Wang, 2002; Wang and Wang, 2005).

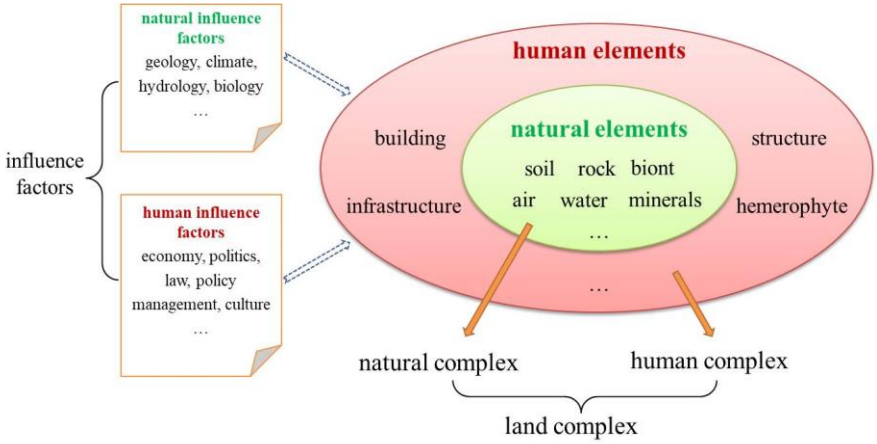

Fig.1 the concept of a land complex

Based on the concepts of land and engineering, we argue that land engineering essentially refers to the artificial transformation of an existing land complex, and the result of land engineering is the creation of a new land complex. And because a land complex itself cannot be completely eliminated, the creation of a new land complex is actually the reconstruction of the old land complex through the artificial reorganization and rebuilding of various elements that constitute a land complex. The reconstruction process is the systematic and comprehensive employment of science and technology to meet human needs, and includes sub-processes like investigation, evaluation, planning, design, construction, supervision, and maintenance.

3.2 Uniqueness of the discipline

① Here natural elements include soil, rock, biont (mainly refers to natural vegetation), air (mainly refers to the air near the surface), water, mineral resource, and so on. Human elements consist of building, structure, infrastructure(such as road, pipe utility), hemerophyte (cultivated plant, such as crop, planting tree), and so on.

② Here natural factors (natural forces influencing land) include geology, climate, hydrology, biology(mainly refers to wild animals), and so on. Human factors (human forces influencing land) consist of economic, politic, law, policy, culture, management, and so on.

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A unique discipline cannot be replaced by another, but what is the uniqueness of the discipline of land engineering, or how is land engineering discipline not to be replaced by other land or engineering disciplines? The answer to this question is strongly associated with the answer to the previous question. Logically, the uniqueness of the discipline stems from the particularity of the study subject. Specifically speaking, the uniqueness of the discipline of land engineering has two aspects, which are consistent with each other.

First, land engineering studies how to transform an old land complex to a new land complex, and aims to create a new land complex from an old complex. This distinguishes land engineering discipline from other sub-disciplines of land science (e.g., land pure science, land technology, land management), which study how to understand and utilize a land complex (Wang et al., 2017). According to the distinction between pure science, technology and engineering (UNESCO et al., 2010), we believe that land engineering studies how to apply theories and tools to transform land, and the result of land engineering is new land complexes which are input materials of production through land management. This is quite not like land pure science whose results are theories and not like land technology whose results are tools.

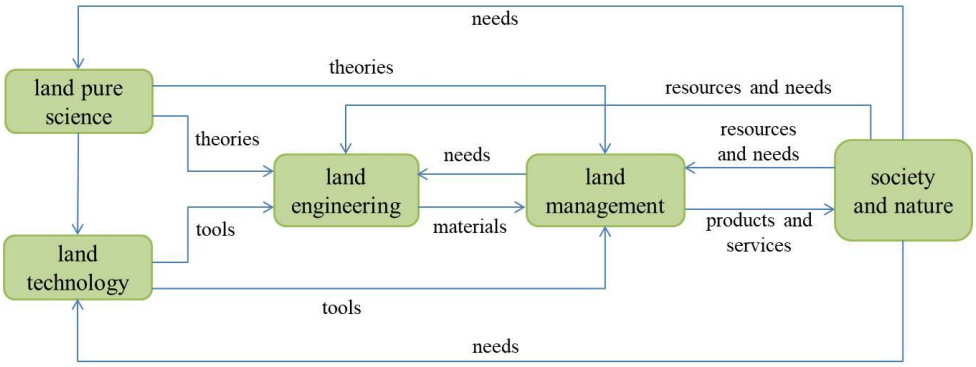

Fig.2 the relationship between the different modules of land science

Second, land engineering studies the comprehensive and integrated reorganization or rebuilding of various elements of land as a complex (two and more elements of land are changed together in land engineering activity), and it especially emphasizes the comprehensiveness and integrality (Xu, 1981, 1986). This makes land engineering significantly different from the discipline of single engineering (e.g., soil engineering, water engineering, road engineering, vegetation engineering), which studies the construction or reconstruction of certain element (e.g., soil, water, road, vegetation) of a land complex.

3.3 Theory system and core theory of the discipline

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Existing research has put forward various theories related to land engineering. But what is the relationship of different theories, and what is the core theory? The existing research still has no accurate answers and consensus.

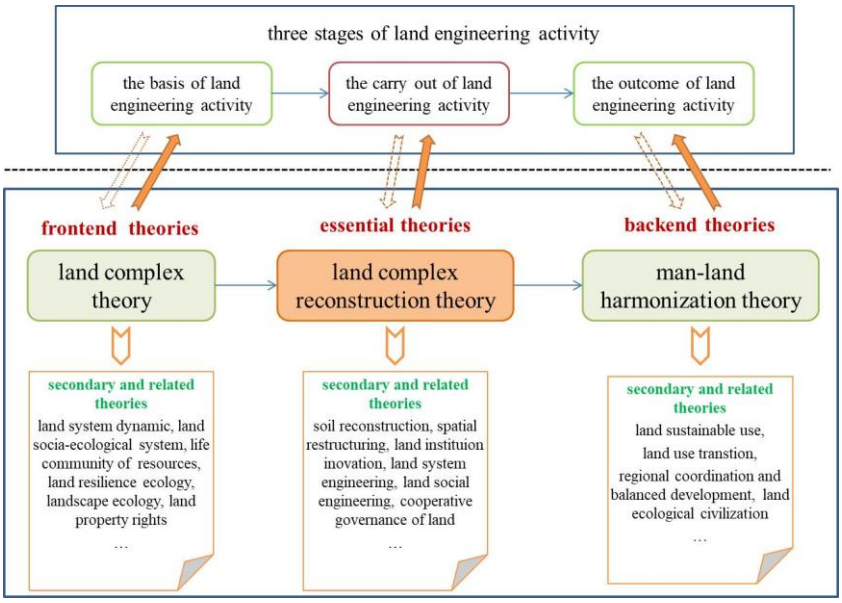

Fig.3 the theoretical system of land engineering

For the first question, the existing research hasn't really explored this. We believe that the related theories can be systematized according to the process of land engineering activity, which can be broken down into three stages. Accordingly, the theories of land engineering can be divided into three categories: frontend theories, essential theories and backend theories. Each category of theory consists of a main theory and a series of secondary and related theories. Our view of the theoretical system of land engineering discipline is detailed in Fig.3.

For the second question, the existing research has provided inaccurate answers. There is a view that the theory of soil reconstruction is the core theory of land engineering as an academic discipline (Han, 2016, 2017a; Hu et al., 2010, 2017). There is another view that spatial restructuring is the nature of land engineering (Long, 2013, 2014).The both views are one-sided and unscientific. Soil reconstruction is only the core issue of some land engineering activities (mainly is contaminated and destroyed land remediation), while spatial restructuring is only one aspect of land engineering. For examples, the renewal of buildings is the core issue and property rights rearrangement is an important aspect in urban land redevelopment and production capacity increase is the core issue and production mode change is an important aspect in high-standard farmland construction. We argue that the core issue of land engineering is the artificial

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reorganization and rebuilding of the various elements of land as a complex, and the core theory of the discipline is the theory of land complex reconstruction, while soil reconstruction or spatial restructuring is only the secondary theory. It is worth noting that spatiality and dynamism are basic properties of a land complex, the reconstruction of a land complex inevitably has spatial and temporal dimensions, and mainly occurs at small and medium spatial-temporal scales which can be better controlled by humans.

3.4 Orientation and mission of the discipline

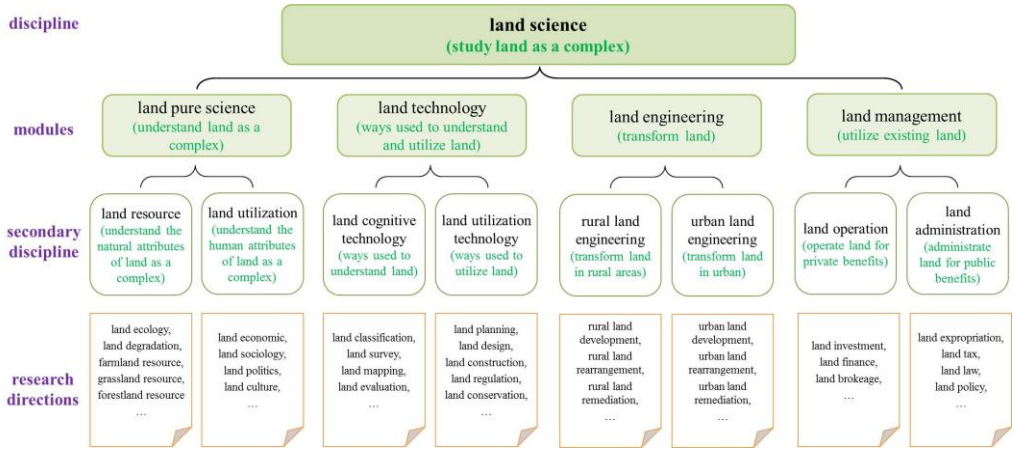

Fig.4 the orientation of land engineering within the discipline of land science

Land engineering is a branch of land science, and the orientation of the discipline should be viewed from the perspective of land science (Wang et al. 2017). Land science takes land as a complex to research in four modules: pure science, technology, engineering and management. Land engineering research is actually the engineering level of research on land as a complex, providing better materials for utilizing land with management (utilize land reflects as land management). This quite differs from other land research levels, i.e., land pure science, land technology, and land management, respectively providing theories, tools, and paths for meeting human needs from land. Accordingly, the discipline of land engineering can be positioned as the engineering research module of land science. It is based on land pure science and land technology, and is one basis of land management.

Land engineering is an applied discipline with a strong mission. The direct purpose of land engineering is to reconstruct a land complex, through the reorganization or rebuilding of various elements. However, the reconstruction of a land complex as the direct purpose of land engineering is exogenous. It is derived from land utilization (including three uses: production, living, and ecology), and land utilization is derived from sustainable development (including three aspects:

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economic, social, and ecology). Therefore, the direct mission of land engineering is to provide better materials (transformed land) for human to utilize, and the final mission of land engineering is to promote sustainable development of mankind.

3.5 Subject matters of the discipline

What are the subject matters of land engineering as an academic discipline? There are several answers to this question. One answer is "land development, land rearrangement, land reclamation, land protection, and land treatment" (Wu et al., 2007). Another answer is "the conversion of non-agricultural land into agricultural land, the readjustment of construction land, the conversion of low-quality land into high-quality land, and the remediation of contaminated and destroyed land" (Han, 2017a). A further answer is "land development, land rearrangement, land reclamation, and land remediation" (Hu et al., 2017). However, these answers are not perfect and still have flaws, such as unclear concepts, incompletion, and lack of logic and system. The subject matters of land engineering discipline should be established on the basis of clear concept definition, include all related activities, and be characterized by a logic system.

By induction and deduction, land engineering activities fall into two categories according to location difference: rural land engineering and urban land engineering, and can be classified into four categories on basis of object difference: land development, land rearrangement, land protection and land remediation. Land development engineering is the artificial conversion of land use, specifically is the conversion of low-benefit land use to high-benefit land use, such as wasteland to farmland, farmland to urban land, and vacant land to residential land. Land rearrangement engineering refers to the artificial adjustment of land use structure, which often involves many property righters and is implemented by public authorities, such as high-standard farmland construction, hollowed village renovation and urban village reconstruction. Land improvement engineering refers to artificially change the bad character of land, such as saline-alkaline land amelioration, the conversion of slope farmland into terrace, and dangerous and old houses renovation. Land protection engineering refers to the artificial prevention of land from loss (potential degradation, pollution, or destruction). Land remediation engineering refers to the artificial restoration of land suffered loss (actual degradation, pollution, or destruction) into its original or a better state, such as mined land remediation, contaminated land remediation, and salinized land treatment.

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Tab.2 the main categories of land engineering activities

category	rural land engineering	urban land engineering
land development	farmland reserve resources development, low hill and gentle slope development, afforestation	urban inefficient land redevelopment, industrial land redevelopment, urban wetland park construction
land rearrangement	high-standard farmland construction, agricultural land rearrangement, rural settlement land rearrangement, hollowed village renovation	urban village reconstruction, “three old” reconstruction, urban land renewal
land improvement	low and medium yield farmland transformation, terracing, land desertification control, saline-alkaline land amelioration, grassland improvement	urban road reconstruction, dangerous and old houses renovation, urban rivers and lakes connection
land protection	basic farmland protection, wetland conservation, farmland shelterbelt construction, water and soil conservation	urban greenbelt construction, urban green space construction, urban cultural heritage protection
land remediation	mined land reclamation, rural settlement land reclamation, ecological de-farming, overall land ecological rehabilitation	contaminated site remediation, urban ecology remediation, illegal construction control

Therefore, the essential contents of land engineering discipline may be structured to two modules, 5 secondary disciplines of each module, and more than 30 research directions.

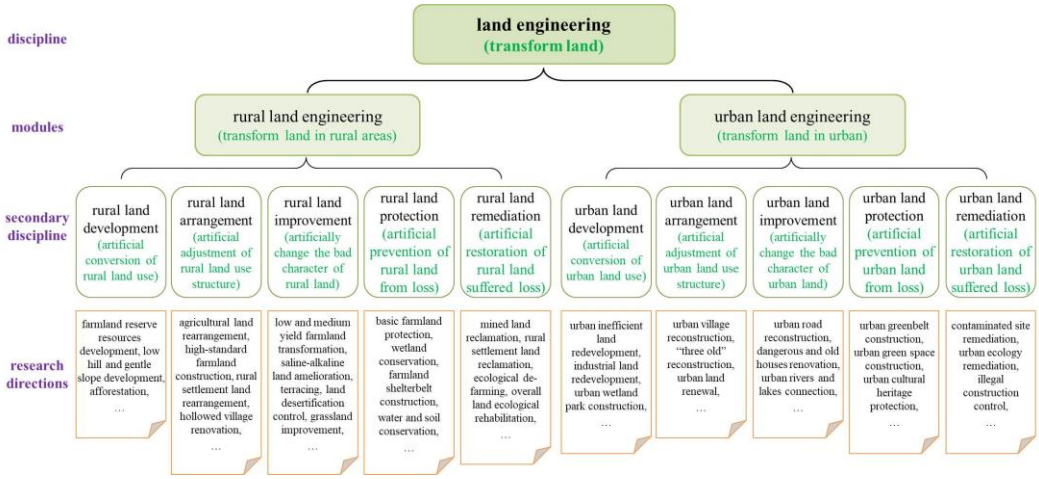

Fig.5 the subject matters within the discipline of land engineering

It is important to point out that land engineering is the systematic and comprehensive employment of science and technology. Various technologies are also the organic components of the discipline of land engineering (Hu et al., 2017), such as land survey, land evaluation, land planning, land design and other technologies. However, it should be noted that the various technologies are only instrumental but not essential contents of the discipline.

4. Conclusions and recommendations

Land engineering is a specific new discipline in China. The bachelor major of land

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engineering was officially approved and established lately since in 2017, but the birth of the discipline of land engineering dates back 40 years ago. It has passed through four development stages, including the incubation stage in 1978-1985, the initial stage in 1986-1997, the growth stage in 1998-2011, and the expanding stage from 2012 to present. The discipline of land engineering takes land engineering activity as the study object, which is the artificial transformation of a land complex. There are three categories of theories related to land engineering: frontend theories, essential theories and backend theories, and the theory of land complex reconstruction is the core theory underpinning the discipline. Studying how to transform an old land complex to a new land complex, or studying the comprehensive and integrated reorganization or rebuilding of various elements of land as a complex, is the unique feature that distinguishes the discipline of land engineering from other land or engineering disciplines. The discipline of land engineering, as the engineering research module of land science, is based on land pure science and land technology, and is one basis of land management. The direct mission of land engineering is to provide better materials (transformed land) for human to utilize, and the final mission is to promote sustainable development. Land engineering as an academic discipline consists of two modules (rural land engineering and urban land engineering), five secondary disciplines of each module (land development, land rearrangement, land improvement, land protection, and land remediation), and more than 30 research directions.

For the further development of land engineering discipline, researchers should continue to make active progress, such as enriching the contents, deepening the theoretical research, and tackling the tough technological problems. The immaturity of land pure science and land technology will restrict the development of land engineering. The discipline of land engineering should be integrated into land science, enabling them to grow together, with a need for more interdisciplinary integration. It is also necessary to draw on multi-disciplinary research results (e.g., soil, water, biology, ecology, environment, geography, economy, management, information, and materials). And there is a need to actively build the research platforms and cultivate the faculties of land engineering. The junior, bachelor, master, and doctorate subjects and courses of land engineering should be established in more colleges and universities, so that the technological talents of land engineering can be trained and provided at all levels to meet social needs.

Land problems are ubiquitous for every country. Land engineering is indispensable to solve

land problems to meet human needs. Building and developing land engineering as a relatively independent discipline is necessary. The development of land engineering as a discipline in China will provide experience and inspiration to other countries.

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