

Chapter 2

Mechanisms with Illustrations in Ancient Books

Abstract There are many technical books with mechanical illustrations in ancient China in which the texts and illustrations are coordinated to introduce technologies and production processes from a variety of primitive industries during the time periods of these books. This chapter introduces five representative technical books including, *Nong Shu* 《農書》 by *Wang Zhen* (王禎), *Wu Bei Zhi* 《武備志》 by *Mao Yuan-yi* (茅元儀), *Tian Gong Kai Wu* 《天工開物》 by *Song Ying-xing* (宋應星), *Nong Zheng Quan Shu* 《農政全書》 by *Xu Guang-qi* (徐光啓), and *Qin Ding Shou Shi Tong Kao* 《欽定授時通考》. The contents and the historical background of these books are presented. In these five books, there are a total of 96 movable devices.

2.1 *Nong Shu* 《農書》 by *Wang Zhen* (王禎) (AD 1313)

The book *Nong Shu* 《農書》, authored by *Wang Zhen* (王禎), was printed and published in the 2nd year (AD 1313) of Era *Huangqing* (皇慶) in the reign of Emperor *Renzong* (仁宗) of the *Yuan* Dynasty (AD 1271–1368). It systematically introduced the agricultural works on a large scale during the *Yuan* Dynasty. It is a masterpiece that summarizes the production experiences and the agricultural technologies in the subject's time period. Figure 2.1 shows the cover page and original preface, published by the *Jinan Shan-Cheng* Printing Bureau (濟南善成印務局) in 1924 (Wang 1924). There are 51 mechanisms with illustrations in *Nong Shu*, as listed in Table 2.1. The contents and historical background of this book are introduced as follows.

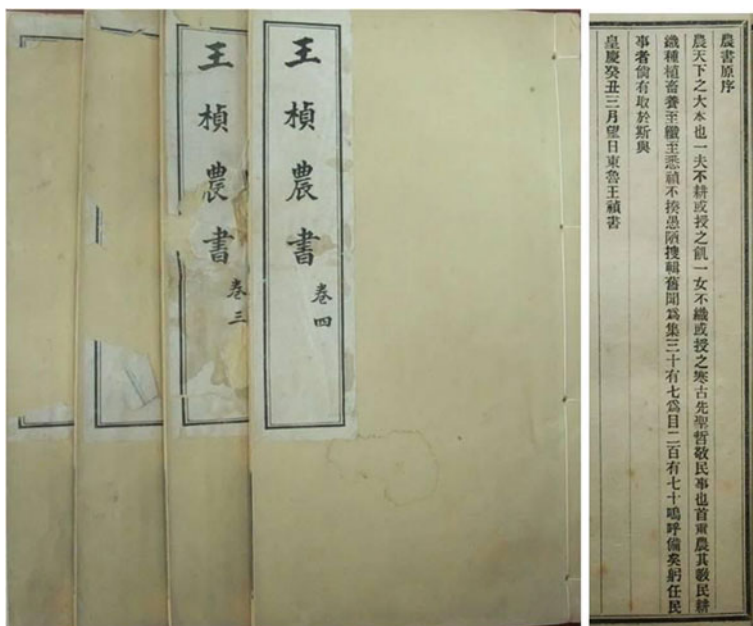


Fig. 2.1 Cover page and original preface of *Nong Shu* 《農書》 (Wang 1924)

2.1.1 Contents

Nong Shu 《農書》 has 370 sets in 37 volumes. It can be divided into three parts: *Nong Sang Tong Jue* 《農桑通訣》, *Bai Gu Pu* 《百穀譜》, and *Nong Qi Tu Pu* 《農器圖譜》, outlined as follows (Wang 1991).

2.1.1.1 *Nong Sang Tong Jue* 《農桑通訣》

This section generally discusses the origins and the historical development of agriculture in ancient China. It not only explains the importance of developing agriculture and sericulture as well as the importance of saving food to prepare for future droughts, but also introduces the agricultural production experience in ancient China, such as plowing, sowing, cultivating, fertilizer managing, harvest storing, etc. In addition, there are some elaborations on the technologies of planting, feeding poultry, and livestock.

2.1.1.2 *Bai Gu Pu* 《百穀譜》

Bai Gu Pu 《百穀譜》 introduces the cultivation points for more than 80 kinds of crops and puts them into different categories. A variety of food and economic

Table 2.1 Mechanisms with illustrations in ancient books (96 items)

Mechanism names		Books				
		Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Li Ze (碾磑)		Lei Si 《耒耜》			Nong Qi 《農器》	
Liu Zhe (礪磑)		Lei Si 《耒耜》			Nong Qi 《農器》	
Gun Zhou (輓軸)		Pa Ba 《杷杷》			Nong Qi 《農器》	Shou Huo 《收穫》
Dun Che (鈍車)		Lei Si 《耒耜》			Nong Qi 《農器》	
Shi Tuo (石陀)				Nai Li 《乃粒》		
Xia Ze Che (下澤車)		Zhou Chi 《舟車》				
Da Che (大車)		Zhou Chi 《舟車》				
Tui Lian (推鎌)		Zhi Ai 《鉏艾》			Nong Qi 《農器》	
Mai Long (麥籠)		Mou Mai 《麴麥》			Nong Qi 《農器》	Shou Huo 《收穫》
He Gua Da Che (合掛大車)				Zhou Chi 《舟車》		
Nan Fang Du Tui Che (南方獨推車)				Zhou Chi 《舟車》		
Shuang Qian Du Lun Che (雙譚獨輪車)				Zhou Chi 《舟車》		
Feng Che Shan (風車扇)		Chu Jiu 《杵臼》		Sui Jing 《碎精》		Gong Zhi 《攻治》

(continued)

Table 2.1 (continued)

Mechanism names		Books				
		Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Mo (碓)		Chu Jiu 《杵臼》		Sui Jing 《碎精》	Nong Qi 《農器》	Gong Zhi 《攻治》
Shui Mo (水磨)		Li Yong 《利用》			Shui Li 《水利》	Gong Zhi 《攻治》
Xiao Nian (小碾)				Sui Jing 《碎精》		Gong Zhi 《攻治》
Gun Shi (滾石)				Sui Jing 《碎精》		
Gua Che (刮車)		Guai Gai 《灌漑》				
Tong Che (筒車)		Guai Gai 《灌漑》		Nai Li 《乃粒》		
Long Wei (龍尾)			Jun Zi Cheng 《軍資乘》		Shui Li 《水利》	Guai Gai 《灌漑》
Chao Che (槲車)			Jun Zi Cheng 《軍資乘》		Shui Li 《水利》	Guai Gai 《灌漑》
Wang Lo Che (望樓車)			Jun Zi Cheng 《軍資乘》		Shui Li 《水利》	Tai Xi Sui Fa 《泰西水法》
Hao Qiao (壕橋)			Jun Zi Cheng 《軍資乘》			
Yang Feng Che (揚風車)			Jun Zi Cheng 《軍資乘》			
Fen Wen Che (鎮輜車)			Jun Zi Cheng 《軍資乘》			
Yun Ti (雲梯)			Jun Zi Cheng 《軍資乘》			

(continued)

Table 2.1 (continued)

Mechanism names	Books				
	Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Pao Che (砲車)		Jun Zi Cheng 《軍資乘》			
Zhuang Che (撞車)		Jun Zi Cheng 《軍資乘》			
Lei (擂)		Jun Zi Cheng 《軍資乘》			
Lang Ya Pai (狼牙拍)		Jun Zi Cheng 《軍資乘》			
Man (幔)		Jun Zi Cheng 《軍資乘》			
Huo Zi Ban Yun Lun (活字板韻輪)	Ma Zhu 《麻字》				
Mu Mian Jiao Che (木棉攪車)	Kuang Xu 《繡架》			Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》
Bo Che (絞車)	Ma Zhu 《麻字》			Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》
Tao Che (陶車)			Tao Yan 《陶埏》		
Ta Dui (踏碓) Dui Chong (碓舂)	Chu Jiu 《杵臼》		Gao Yi 《膏液》 Sui Jing 《碎精》	Nong Qi 《農器》	Gong Zhi 《攻治》
Cao Dui (槽碓)	Li Yong 《利用》			Shui Li 《水利》	Gong Zhi 《攻治》
Si (鋤)	Zhi Ai 《鉏艾》			Nong Qi 《農器》	Mu Shi 《牧事》

(continued)

Table 2.1 (continued)

Mechanism names	Books				
	Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Sang Jia (桑夾)	Can Sang 《蠶桑》			Can Sang 《蠶桑》	Can Shi 《蠶事》
Lian Jia (連枷)	Pa Ba 《杷杷》		Sui Jing 《碎精》	Nong Qi 《農器》	Shou Huo 《收穫》
Da Jia (打枷)			Jia Bing 《佳兵》		
Quan Heng (權衡)					
He Yin (鶴飲)					
Jie Gao (桔槔)	Guai Gai 《灌漑》		Nai Li 《乃粒》	Shui Li 《水利》	Tai Xi Sui Fa 《泰西水法》
Hong Xi (虹吸)					Guai Gai 《灌漑》
Heng Sheng (恒升)		Jun Zi Cheng 《軍資乘》		Shui Li 《水利》	Tai Xi Sui Fa 《泰西水法》
Yu Heng (玉衡)		Jun Zi Cheng 《軍資乘》		Shui Li 《水利》	Tai Xi Sui Fa 《泰西水法》
Shi Nian (石礮)	Chu Jiu 《杵臼》			Nong Qi 《農器》	Tai Xi Sui Fa 《泰西水法》
Nian (礮)			Sui Jing 《碎精》		
Niu Nian (牛礮)			Sui Jing 《碎精》		
Shui Nian (水礮)	Chu Jiu 《杵臼》			Shui Li 《水利》	Gong Zhi 《攻治》
Gun Nian (靛礮)	Chu Jiu 《杵臼》			Nong Qi 《農器》	Gong Zhi 《攻治》
Hai Qing Nian (海青礮)					

(continued)

Table 2.1 (continued)

Mechanism names		Books				
		Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Long (龍)		Chu Jiu 《杵臼》		Gao Yi 《膏液》	Nong Qi 《農器》	Gong Zhi 《攻治》
Mu Long (木龍)				Sui Jing 《碎精》		
Tu Long (土龍)				Sui Jing 《碎精》		
				Sui Jing 《碎精》		
Mian Luo (麤羅)				Ye Zhu 《冶鑄》		Gong Zhi 《攻治》
Yang Shan (鷗扇)				Chui Duan 《捶鍛》		Gong Zhi 《攻治》
Feng Xiang (風箱)				Wu Jin 《五金》	Nong Qi 《農器》	Gong Zhi 《攻治》
Wo Lun Shi Shui Pai (臥輪式水排)		Li Yong 《利用》			Shui Li 《水利》	
Shui Ji Mian Luo (水磨麤羅)		Li Yong 《利用》			Shui Li 《水利》	Gong Zhi 《攻治》
Tie Nian Cao (鐵碾槽)				Dan Qing 《丹青》		
Zha Zhe Ji (榨蔗機)				Gan Shi 《甘嗜》		
Lian Mo (連磨)		Chu Jiu 《杵臼》				
Shui Mo (水磨)				Sui Jing 《碎精》		
Lian Er Shui Mo (連二水磨)					Shui Li 《水利》	Gong Zhi 《攻治》

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Table 2.1 (continued)

Mechanism names	Books		Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
	Nong Shu 《農書》					
Shui Zhuan Lian Mo (水轉連磨)	Li Yong 《利用》				Shui Li 《水利》	Gong Zhi 《政治》
Shui Long (水龍)	Li Yong 《利用》				Shui Li 《水利》	
Lv Zhuan Tong Che (轆轉筒車)	Guai Gai 《灌漑》				Shui Li 《水利》	Guai Gai 《灌漑》
Niu Zhuan Fan Che (牛轉翻車)	Guai Gai 《灌漑》		Nai Li 《乃粒》		Shui Li 《水利》	Guai Gai 《灌漑》
Shui Zhuan Fan Che (水轉翻車)	Guai Gai 《灌漑》		Nai Li 《乃粒》		Shui Li 《水利》	Guai Gai 《灌漑》
Shui Che (水車)			Nai Li 《乃粒》			
Feng Zhuan Fan Che (風轉翻車)						
(only text without illustration)						
Shui Dui (水碓)	Li Yong 《利用》			Sui Jing 《碎精》	Shui Li 《水利》	Gong Zhi 《政治》
Ji Dui (機碓)						
Lian Ji Dui (連機碓)						
Li Lun Shi Shui Pai (立輪式水排)	Li Yong 《利用》					
(only text without illustration)						
Shai Gu (篩穀)			Sui Jing 《碎精》			
Lv Long (轆龍)	Chu Jiu 《杵臼》		Sui Jing 《碎精》		Nong Qi 《農器》	

(continued)

Table 2.1 (continued)

Mechanism names	Books				
	Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Lu Lu (轆轤)	Guai Gai 《灌漑》		Nai Li 《乃粒》	Shui Li 《水利》	Guai Gai 《灌漑》
Shou Dong Fan Che (手動翻車)			Nai Li 《乃粒》		
Ba Che (拔車)					
Jiao Ta Fan Che (腳踏翻車)	Guai Gai 《灌漑》		Nai Li 《乃粒》	Shui Li 《水利》	Guai Gai 《灌漑》
Ta Che (踏車)					
Gao Zhuan Tong Che (高轉筒車)	Guai Gai 《灌漑》		Nai Li 《乃粒》	Shui Li 《水利》	Guai Gai 《灌漑》
Shui Zhuan Gao Che (水轉高車)	Guai Gai 《灌漑》			Shui Li 《水利》 (no illustration)	
Ru Shui (入水)			Zuo Xian 《作鬴》		
Ru Jing (入井)			Fan Shi 《礮石》		
Zao Jing (鑿井)			Zhu Yu 《珠玉》		
Mo Chuang (磨床) (a cutting jade device)			Zuo Xian 《作鬴》		
Zha You Ji (榨油機)			Zhu Yu 《珠玉》		
Pan Che (蟠車)	Ma Zhu 《麻苧》		Gao Yi 《膏液》	Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》

(continued)

Table 2.1 (continued)

Mechanism names	Books				
	Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Xu Che (架車)	Kuang Xu 《續架》			Can Sang 《蠶桑》	Can Shi 《蠶事》
Gan Mian Che (趕棉車)			Nai Fu 《乃服》		
Tan Mian (彈棉)			Nai Fu 《乃服》		
Shou Yao Fang Che (手搖紡車)			Nai Fu 《乃服》		
Fang lu (紡樓)					
Wei Che (緯車)	Zhi Ren 《織紵》		Nai Fu 《乃服》	Can Sang 《蠶桑》	Can Shi 《蠶事》
Fang Wei (紡緯)	Zhi Ren 《織紵》			Can Sang 《蠶桑》	Can Shi 《蠶事》
Jing Jia (經架)	Kuang Xu 《續架》			Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》
Mu Mian Kuang Chuang (木棉軒床)					
Original Crossbow		Jun Zi Cheng 《軍資乘》 Zhen Lian Zhi 《陣練制》	Jia Bing 《佳兵》		
Chu State Repeating Crossbow (No ancient document recorded)					
Zhuge Repeating Crossbow		Jun Zi Cheng 《軍資乘》	Jia Bing 《佳兵》		

(continued)

Table 2.1 (continued)

Mechanism names	Books				
	Nong Shu 《農書》	Wu Bei Zhi 《武備志》	Tian Gong Kai Wu 《天工開物》	Nong Zheng Quan Shu 《農政全書》	Qin Ding Shou Shi Tong Kao 《欽定授時通考》
Sao Che (纜車)	Can Sao 《蠶繅》		Nai Fu 《乃服》	Can Sang 《蠶桑》	Can Shi 《蠶事》
Jiao Ta Fang Che (腳踏紡車)	Kuang Xu 《繅絮》		Nai Fu 《乃服》	Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》
Mu Mian Xian Jia (木棉線架)	Ma Zhu 《麻苧》				
Xia Fang Che (小紡車)					
Mu Mian Fang Che (木棉紡車)					
Pi Dai Chuan Dong Fang Che (皮帶傳動紡車)	Ma Zhu 《麻苧》				
Da Fang Che (大紡車)	Li Yong 《利用》			Can Sang Guang Lei 《蠶桑廣類》 Shui Li 《水利》	Sang Yu 《桑餘》
Shui Zhuan Da Fang Che (水轉大紡車)					
Xie Zhi Ji (斜織機)	Ma Zhu 《麻苧》		Nai Fu 《乃服》	Can Sang Guang Lei 《蠶桑廣類》	Sang Yu 《桑餘》
Yao Ji (腰機)	Zhi Ren 《織紵》				
Bu Ji (布機)	Zhi Ren 《織紵》				
Wo Ji (臥機)	Zhi Ren 《織紵》		Nai Fu 《乃服》	Can Sang 《蠶桑》	Can Shi 《蠶事》
Ti Hua Ji (提花機)					
Hua Ji (花機)					
Zhi Ji (織機)					

crops, and their origins, species and cultivation methods are also included. This section adds the descriptions on the characteristics of the plants as well.

2.1.1.3 Nong Qi Tu Pu 《農器圖譜》

This section is a distinguishing feature of the book, accounting for four fifths of the whole book's contents. It collects 300 pieces of illustrations with texts, detailing the structures and usages of a variety of agricultural equipment and major facilities. It can be considered as the earliest historical materials available coupled with illustrations about farming tools. After the *Yuan* Dynasty, the text descriptions for farm tools in the agricultural books were transcribed from the contents of *Nong Shu* 《農書》.

Nong Shu 《農書》 discusses both northern and southern agricultural technologies, describes the land usage and farm irrigation, and widely introduces a variety of agricultural devices. The book is valuable for studying ancient Chinese agriculture. *Tian Zhi Meng* 《田制門》 (farm measure system), one part of the book, has two appendices: *Fa Zhi Chang Sheng Wu* 《法制長生屋》 and *Zao Huo Zhi Yin Shu Fa* 《造活字印書法》. Both of them have important contributions to the future fireproofing of buildings and letterpress printing technology, respectively.

2.1.2 Historical Background

Nong Shu 《農書》 was completed in the heyday of the *Yuan* Dynasty. The society was relatively stable and has rapid developments in culture and education. After “*Yuan Shih-tsu*” Kublai_Khan (元世祖忽必烈) (AD 1215–1294) became the emperor of the *Yuan* Dynasty, he adopted a series of policies to restore and develop agricultural production, in order to increase the number of buildings and population. Under such policies, many of the new production technologies were created. As a result, this book in one aspect collected old agricultural technologies and extensively referred to ancient agricultural recordings in history books. In another aspect, it summarized contemporary experiences, new technologies, and the author's own inspection, research, and results for agricultural knowledge.

Wang Zhen (王禎), the author of *Nong Shu* 《農書》, was born at Dongping County in Shandong Province (山東省東平縣). His adult name is *Bo Shang* (伯善). He was a magistrate of Jingde County in Xuan Province (宣州旌德縣) in the 1st year (AD 1295) of Era *Yuanzhen* (元貞) of the reign of Emperor *Chengzong* (成宗) of the *Yuan* Dynasty, and then he became another magistrate in *Yuanfeng* County in Xin Province (信州永豐縣) in the 4th year (AD1300) of Era *Dade* (大德) of the reign of Emperor *Chengzong* (成宗). *Nong Shu* 《農書》 was completed during these two government positions' terms, extending for more than 10 years. *Wang Zhen* (王禎) traveled around different places and earned so much experience that he could summarize and integrate southern and northern agricultural systems.

During his terms as magistrates, he advised the farmers in farming and sericulture, propagated more advanced farming technologies, developed *Nong Sang Mian Ma* (農桑棉麻, meaning all kinds of agricultural production), and reformed farming tools as he kept accumulating new experiences. In addition to collecting and documenting all kinds of crop-planting methods as well as the production methods of farming tools, he also designed some innovative agricultural devices.

Nong Shu 《農書》 delivers a philosophy in agriculture and aims at teaching people about production. Therefore, most farming tools in the book, the manufacturing methods, the parts assembly, sizes, and transmission modes are described carefully and truthfully. With lots of explanatory illustrations, this book can be considered a highly valuable textbook about agriculture of that time. Unlike *Jia* 《齊民要術》 (Jia 1968) or other agricultural books that are only applicable in some areas, *Nong Shu* 《農書》 makes a comprehensive description about ancient China's whole agricultural system including the seasons, climate, irrigation, soil, and other conditions in that time, as well as farming tools and production technologies, etc. It is the first book that systematically studies the agriculture in southern and northern China.

2.2 Wu Bei Zhi 《武備志》 by Mao Yuan-yi (茅元儀) (AD 1621)

The book *Wu Bei Zhi* 《武備志》, authored by *Mao Yuan-yi* (茅元儀, AD 1594–1640) was printed and published in the 1st year (AD 1621) of the Era *Tianqi* (天啓) of the reign of Emperor *Xizong* (熹宗) of the *Ming* Dynasty (AD 1368–1644). This book is the most comprehensive military masterpiece with the largest scale and the most amount of content. It is known as an encyclopedia of classical military study. Figure 2.2 shows the cover page and original preface, published by *Henan Education Press* (海南出版社) in 2001 (Mao 2001). There are 16 mechanisms with illustrations in *Wu Bei Zhi*, as listed in Table 2.1. The contents and historical background of this book are introduced as follows:

2.2.1 Contents

Wu Bei Zhi 《武備志》 has a total of 240 volumes, over two million words, and 738 illustrations. It can be divided into five parts: *Bing Jue Ping* 《兵訣評》, *Zhan Lue Kao* 《戰略考》, *Zhen Lian Zhi* 《陣練制》, *Jun Zi Cheng* 《軍資乘》, and *Zhan Du Zai* 《占度載》, outlined as follows (Wang 2004).



Fig. 2.2 Cover page and original preface of *Wu Bei Zhi* 《武備志》 (Mao 2001)

2.2.1.1 Bing Jue Ping 《兵訣評》

This part contains 18 volumes. It selects and copies the full text of famous military books before the *Ming* Dynasty (AD 1368–1644), such as *Sun Zi* 《孫子》, *Wu Zi* 《吳子》, *Si Ma Fa* 《司馬法》, *Liu Tao* 《六韜》, *Wei Liao Zi* 《尉繚子》, *San Lue* 《三略》, and *Li Wei Gong Wen Dui* 《李衛工問對》. In addition, it contains parts of *Shen Ji Zhi Di Tai Bai Yin Jin* 《神機制敵太白陰經》 and *Hu Ling Jin* 《虎鈴經》. By evaluating the main ideas of those books, the author elaborates his understanding and viewpoints on those previous military studies.

2.2.1.2 Zhan Lue Kao 《戰略考》

This part contains 33 volumes. It collects 613 famous war stories from different dynasties in the order of time. *Mao* reviewed the war strategies within the stories and compared them with each other, trying to gain lessons from those histories as references for the warfare in his time.

2.2.1.3 Zhen Lian Zhi 《陣練制》

This part contains 41 volumes and can be divided into two categories: *Zhen* 《陣》 and *Lian* 《練》. *Zhen* 《陣》 details the different tactical deployments with illustrations before the *Ming* Dynasty (AD 1368–1644). *Lian* 《練》 describes the soldiers' recruitment, unit establishment, reward and punishment, education and instruction, and training.

2.2.1.4 Jun Zi Cheng 《軍資乘》

This part contains 55 volumes and can be divided into eight categories including camps, war, attack, defend, water, fire, salary, and horse. It discusses how to prepare materials for military use, such as military devices, gunpowder, war tanks,

warships, food, and so on. This category is a very important reference for ancient military supplies and logistics.

2.2.1.5 Zhan Du Zai 《占度載》

This part contains 93 volumes and can be divided into two categories: *Zhan* 《占》 and *Du* 《度》. *Zhan* 《占》 reflects the typical viewpoints with regards to astronomy and climate in the author's time, even though many of them are superstitious and ridiculous. *Du* 《度》 mainly describes the basic conditions for military in the *Ming* Dynasty, such as geographical situations, military gates and key places, enemies' situations from the seas and the lands, deployments of military bases, army structure, military wages and finance, etc.

2.2.2 Historical Background

The author of *Wu Bei Zhi* 《武備志》 is **Mao Yuan-yi** (茅元儀, AD 1594–1640). His adult name is *Zhi Sheng* (止生) and his pseudonym is *Shi Ming* (石民). He was born in *Wuxing* County of *Zhejiang* Province (浙江省吳興縣) in the 2nd year (AD 1594) of Era *Wanli* (萬曆) of the reign of Emperor *Shenzong* (神宗), and died in the 13th year (AD 1640) of Era *Chongzhen* (崇禎) of the reign of Emperor *Sizong* (思宗) of the *Ming* Dynasty (AD 1368–1644). In his youth, *Mao* was a low level official in the Imperial Academy. He liked studying books even when he was still young, especially military books. Several years later, he became a famous military expert and acclaimed by many military leaders (Wang 2004).

In 1616, the Jurchen people (女真族) from the Northeast established the *Houjin* (後金) regime. The regime's leader called himself *Jinguo Khan* (金國汗, the ruler of *Houjin*). Several years later, the leader attacked the *Ming* Dynasty. At that time, the power of the *Ming* Dynasty was controlled by eunuch officials. For some reasons, they weakened the power of the army that led to the failure of *Ming*'s military. Because of anxiety and anger about the political situation, *Mao* decided to write a book for his own military philosophy. He integrated military theories from the past dynasties, weapon technologies, and his own thoughts about how to rule the nation, into the book *Wu Bei Zhi* 《武備志》. This book was printed and published in 1621. Since then, *Mao* became more and more famous. He followed the Scholar *Sun Chen-zong* (孫承宗), leading the army to defend *Houjin* (後金) in the *Liaodong* (遼東) area and recovering many lost territories.

Mao was good not only at conceptualizing theories but also executing them. He wrote many books, but *Wu Bei Zhi* 《武備志》 has the most profound influence on later generations. Although some parts of its contents were copied from other military books, the book still contains his unique military philosophy. For example, *Mao* stated that learning military theories and executing them are both important when training military officers. He encouraged officers to learn military

strategies and tactics, emphasizing military training and the importance of border and coast defense, and he advocated continuing to produce and enhance war weapons, etc.

2.3 Tian Gong Kai Wu 《天工開物》 by Song Ying-xing (宋應星) (AD 1637)

The book *Tian Gong Kai Wu* 《天工開物》 by Song Ying-xing (宋應星, AD 1587–1666) was printed and published in the 10th year (AD 1637) of Era *Chongzhen* (崇禎) of the reign of Emperor *Sizong* (思宗) of the *Ming* Dynasty (AD 1368–1644) and is a comprehensive science and technology book. This book records over 130 production technologies and more than 100 illustrations before the middle age of the *Ming* Dynasty. It depicts the names, the shapes, and the making process of different devices. Figure 2.3 shows the cover page and original preface, published by *Hua Tung Book Company* (華通書局) in 1930 (Song 1930). There are 47 mechanisms with illustrations in *Tian Gong Kai Wu*, as listed in Table 2.1. The contents and historical background of this book are introduced as follows:

2.3.1 Contents

Tian Gong Kai Wu 《天工開物》 has 18 chapters in three volumes (Sun and Sun 1966). The author intentionally arranged the first chapter as *Nai Li* 《乃粒》 (growing of grains) and the last one as *Zhu Yu* 《珠玉》 (pearls and gems). The reason behind this arrangement is that the former “growing of grains” is related to daily food supply, while the latter “pearls and gems” has nothing to do with



Fig. 2.3 Cover page and original preface of *Tian Gong Kai Wu* 《天工開物》 (Song 1930)

people's livelihood. Every chapter is named after two elegant words found in ancient classics. The details of each chapter are explained as follows:

Volume I

- Chapter 1 *Nai Li* 《乃粒》 (growing of grains): farming technologies for food crops
- Chapter 2 *Nai Fu* 《乃服》 (clothing materials): clothes materials, their sources and the processing methods
- Chapter 3 *Zhang Shi* 《彰施》 (dyes): vegetable dyes and the dyeing methods
- Chapter 4 *Sui Jing* 《碎精》 (preparation of grains): processing of grains
- Chapter 5 *Zuo Xian* 《作鹹》 (salt): six methods for manufacturing salt
- Chapter 6 *Gan Shi* 《甘嗜》 (sugar): methods for planting cane and producing sugar

Volume II

- Chapter 7 *Tao Yan* 《陶埏》 (ceramics): manufacturing bricks, tiles, and ceramics
- Chapter 8 *Ye Zhu* 《冶鑄》 (casting): casting and processing of metal devices
- Chapter 9 *Zhou Chi* 《舟車》 (boats and carts): structures and manufacturing methods of boats, ships, and vehicles
- Chapter 10 *Chui Duan* 《錘鍛》 (hammer forging): forging methods for iron and bronze devices
- Chapter 11 *Fan Shi* 《煆石》 (calcination of stones): calcining and heating techniques of lime and coal
- Chapter 12 *Gao Yi* 《膏液》 (vegetable oils and fats): 16 methods to extract vegetable oils and fats
- Chapter 13 *Sha Qing* 《殺青》 (paper): five processes for making paper

Volume III

- Chapter 14 *Wu Jin* 《五金》 (metals): mining and smelting of metals
- Chapter 15 *Jia Bing* 《佳兵》 (weapons): manufacturing methods of weapons, such as bolts, crossbows, repeating crossbows, gunpowder, firearms, landmines, submarine mines, musket, etc.
- Chapter 16 *Dan Qing* 《丹青》 (vermilion and ink): making of ink and pigment as well as the description of *Yin Zhu* (銀朱, mercury sulfide)
- Chapter 17 *Qu Nie* 《麴蘖》 (yeasts): process of making wine
- Chapter 18 *Zhu Yu* 《珠玉》 (pearls and gems): sources and mining of pearls and gems

2.3.2 Historical Background

The agricultural and handicraft industries of the *Ming* Dynasty (AD 1368–1644) became heir to the technological achievements of the previous dynasties. Also, the *Ming* Dynasty imported many new products and technologies from the West to expand and develop its own traditional ones. Therefore, the level of production skills in all aspects had improved at that time.

The author of *Tian Gong Kai Wu* 《天工開物》, **Song Ying-xing** (宋應星, AD 1587–1666) with his adult name as *Chang Geng* (長庚), was born in *Fengxing* County of *Jiangxi* Province (江西省奉新縣) in the 15th year (AD 1587) of Era *Wan Li* (萬曆) of the *Ming* Dynasty, and died around 1666 (Pan 1998). He came from a family whose members had been well-educated for many generations but their power was already on the decline when he was growing up. In his youth, *Song* received the usual classical education and naturally tried to follow the only formal career route open to him by taking the civil service examinations. He passed the public examinations to the level of a provincial graduate in 1615 at the age of 28. During 1616–1631, he attempted the metropolitan examination but this ended in disappointment. In 1631, he tried for the fifth and last time at the age of 44. After his mother died in 1632, he gave up trying to pass the examination and instead served in a number of official capacities. In 1634, *Song* served as a military officer in *Fenxi* County of *Jiangxi* Province (江西省分宜縣) and started to write the literary pieces. In order to finish the extensive and detailed work, he studied and gathered materials over a number of years. It seems that *Song*'s unsuccessful trips to the capital to take the examinations had helped him to gather materials from beyond his native province and provided him with a broad base of knowledge demonstrated in the work. He completed and published his famous book *Tian Gong Kai Wu* 《天工開物》 in 1637.

Tian Gong (天工) refers to the behaviors of nature relative to humans. *Kai Wu* (開物) means processing and producing things from all kinds of natural resources for man's good. The title "*Tian Gong Kai Wu*" (天工開物) emphasizes the behaviors of human and nature as they interact with each other. When man's efforts are combined with nature, useful things can be created from nature through the technologies.

Tian Gong Kai Wu 《天工開物》 has three main features when compared with other ancient Chinese literature. The first is the detailed illustrations that are valuable for later generations in understanding many early Chinese production techniques. Profusely illustrated with over 100 original woodcuts, the book covers practically all major industrial techniques of its time. The second is that the descriptions of the production processes are not only qualitative analysis but are also detailed amounts on the rate of materials and products, the consumption of energy resources, and the dimensions of the instruments, etc. It is a great advancement of the quantitative analysis in ancient Chinese literature. The third is that the book breaks away from Chinese tradition by rarely referencing a previous written work. It is instead written in a style of detailed first-hand data.

Tian Gong Kai Wu 《天工開物》 has been translated into different languages and published in many countries. The influences of the book have spread all over the world. As the historian Joseph Needham pointed out, the vast amount of accurately drawn illustrations in this encyclopedia dwarfed the amount of information provided in previous Chinese encyclopedias, making it a valuable work in the history of Chinese literature (Needham 1954).

2.4 Nong Zheng Quan Shu 《農政全書》 by Xu Guang-qi (徐光啓) (AD 1639)

The book *Nong Zheng Quan Shu* 《農政全書》 authored by *Xu Guang-qi* (徐光啓, AD 1562–1633) was published in the 12th year (AD 1639) of Era *Chongzhen* (崇禎) of the reign of Emperor *Sizong* (思宗) of the *Ming* Dynasty (AD 1368–1644). The book contains manufacturing technologies for ancient agriculture and many aspects of people's livelihood. Figure 2.4 shows the cover page and original preface, printed by *Rei Shu-sen* (任樹森), a publisher in the *Qing* Dynasty (清朝) (AD 1644–1911) in 1837 (Xu 1837). There are 50 mechanisms with illustrations in *Nong Zheng Quan Shu*, as listed in Table 2.1. The contents and historical background of this book are introduced as follows:

2.4.1 Contents

This book can be roughly divided into two parts: agricultural policies and agricultural technologies, including 60 volumes in 12 sections (Shi 1981). The details of each section are as follows:

1. *Nong Ben* 《農本》 (origin of agriculture, 3 volumes)
2. *Tian Zhi* 《田制》 (farm measure system, 2 volumes)
3. *Nong Shi* 《農事》 (farm work, 6 volumes)
4. *Shui Li* 《水利》 (irrigation, 9 volumes)
5. *Nong Qi* 《農器》 (farming tools, 4 volumes)
6. *Shu Yi* 《樹藝》 (food crops cultivation, 6 volumes)
7. *Can Sang* 《蠶桑》 (sericulture)
8. *Can Sang Guang Lei* 《蠶桑廣類》 (other related matters in sericulture, 2 volumes)
9. *Zhong Zhi* 《種植》 (plant cultivation, 4 volumes)
10. *Mu Yang* 《牧養》 (husbandry, 1 volume)
11. *Zhi Zhao* 《製造》 (food production, 1 volume)
12. *Huang Zhen* 《荒政》 (disaster policies, 18 volumes)



Fig. 2.4 Cover page and original preface of *Nong Zheng Quan Shu* 《農政全書》 (Xu 1837)

It summarized all the ancient agricultural experiences and technologies with more than 200 books as references. In addition to introducing ancient Chinese farm tools and devices, the book also added a number of mechanical inventions from the West.

Unlike *Nong Shu* 《農書》 in Sect. 2.1 which was a pure technological agricultural book, this book emphasizes on the philosophy of the agricultural policies on a nation wide basis. This feature helps the book stand out from other large agricultural books. The two sections of the book, *Shui Li* 《水利》 (irrigation) and *Huang Zhen* 《荒政》 (disaster policies) account for most of its content. The former discusses reclamation, irrigation, and other basic elements of agriculture. The latter summarizes floods, droughts, plagues of insects, saving food to prepare for coming droughts, and related rescue plans and policies in the past dynasties. This book has a deep influence on the agriculture policies of later generations (Zhang and Wang 1992).

2.4.2 Historical Background

The author of *Nong Zheng Quan Shu* 《農政全書》 is **Xu Guang-qi** (徐光啓) from Shanghai (上海). His adult name is *Zi Xiang* (子先) and pseudonym is *Xuan Hu* (玄扈). He was born in the 41st year (AD 1562) of Era *Jiaping* (嘉靖) of the reign of Emperor *Shizhong* (世宗) and died in the 6th year (AD 1633) of Era *Chongzhen* (崇禎) of the reign of Emperor *Sizong* (思宗) of the *Ming* Dynasty (AD 1368–1644). He was appointed as an assistant minister, an official who teaches the princesses, and the other government officials. *Xu* conducted several large-scale trials and wrote many agricultural books about planting methods and cultivation technologies. He partnered with western Jesuit missionary Matteo Ricci (利瑪竇), Sabatino de Ursis (熊三拔), et al., to translate several foreign books, such as *Taixi Shufa* 《泰西水法》 (Hydraulic machinery of the West). Therefore, *Nong Zheng Quan Shu* 《農政全書》 contained several western farming tools recorded in *Taixi Shufa* 《泰西水法》.

In 1521–1566, the troops in the capital needed a large amount of food that had to be transported from downstream of the *Yangtze* River (長江). This action not only costs a lot of time but also a large amount of money. In order to consolidate national defense and stabilize people's livings, *Xu* advocated opening up the vast abandoned wastelands in the northwest. As a result, the opening up of wasteland and irrigating then became an important issue. Therefore, *Nong Zheng Quan Shu* 《農政全書》 contains almost one half of the book's content relating to agricultural policies, and the other half documenting agricultural technologies (Zhang and Wang 1992).

2.5 Qin Ding Shou Shi Tong Kao 《欽定授時通考》 by Ortai, et al. (鄂爾泰等人)

The book *Qin Ding Shou Shi Tong Kao* 《欽定授時通考》 was completed in the 7th year (AD 1742) of Era *Qianlong* (乾隆) in the reign of Emperor *Gaozong* (高宗) of the *Qing* Dynasty (AD 1644–1911). Scholar *Ortai* (鄂爾泰) (AD 1677–1754), *Zhang Ting-yu* (張廷玉) (AD 1672–1755) and 40 other people compiled this book by the emperor's orders. Figure 2.5 shows the cover page and original preface, printed by *Fu Wen Bureau* (富文局) in 1902 (Ortai et al. 1902). There are 46 mechanisms with illustrations in *Qin Ding Shou Shi Tong Kao*, as listed in Table 2.1. The contents and historical background of this book are introduced as follows:

2.5.1 Contents

Qin Ding Shou Shi Tong Kao 《欽定授時通考》 collected and reorganized over 400 types of ancient agricultural literature. The book mainly emphasized crops production, while other topics are also covered including forestry, logging, fishery, etc. It has 78 volumes with over 500 related illustrations and can be divided into eight categories (Ortai et al 1965). Each category is outlined as follows:

2.5.1.1 Tian Shi Men 《天時門》

Tian Shi 《天時》 refers to the periods and seasonal changes during which crops' growth must be monitored. This part summarizes the farmers' activities in the different solar cycles (節氣) in a year.



Fig. 2.5 Cover page and original preface of *Qin Ding Shou Shi Tong Kao* 《欽定授時通考》 (Ortai et al. 1902)

2.5.1.2 Tu Yi Men 《土宜門》

This category includes identifying directions, choosing locations, measuring dimensions of farms, irrigation, etc., integrating irrigation and drought prevention experiences together.

2.5.1.3 Gu Zhong Men 《穀種門》

This category discusses the origins, characteristics of species, and cultivation methods, etc. A variety of food crops, such as rice, grain, wheat, beans, millet, and others are also described.

2.5.1.4 Gong Zuo Men 《功作門》

This category records the tools needed in every production cycle, from plowing to storing, and their operating tools and methods.

2.5.1.5 Quan Ke Men 《勸課門》

This category records the agricultural orders and policies from past dynasties.

2.5.1.6 Xu Ju Men 《蓄聚門》

This category discusses the storage space for crops and their storage systems against natural disasters, related policies, and other matters.

2.5.1.7 Nong Yu Men 《農餘門》

This category accounts for most of the contents of the book, recording agricultural production, such as fruit trees, vegetables, lumber, economic crops, husbandry, and other sub-agricultural occupations.

2.5.1.8 Can Sang Men 《蠶桑門》

This category records sericulture, silk reeling, and other various matters.

Qin Ding Shou Shi Tong Kao 《欽定授時通考》 is a well-organized and comprehensive masterpiece. In the beginning of every category, the compilers collected related literature from past dynasties and quoted those authors' words from there. Most of the quotes are production experiences accumulated from different

areas. This book not only has instructional and promotional functions to a variety of industries in the *Qing* Dynasty (AD 1644–1911), but it has also deeply influenced agricultural production and study of agriculture (Yi 1981).

2.5.2 Historical Background

Emperor *Gaozong* (高宗, 清朝乾隆皇帝, AD 1711–1799) on one side promulgated a variety of regulations and adopted a series of policies focusing on agriculture in order to enforce his ruling power. On the other side, he ordered his officials to compile a huge number of books intended to foster achievements in culture and education. During his reign, he ordered officials to compile more than 120 kinds of books, making him stand out from the other emperors of the past dynasties. Besides compiling books, he also encouraged the study of agriculture, farming and sericulture, as well as promoting agricultural knowledge and technologies. He ordered that the people be taught about the farming calendar, and he requested all farmers to follow the “farming season” to plow and do other farming activities. Because the compilation of this book was supported by the government, the collections and compilation of literature are more comprehensive than before. Also, the books selected by the compilers when compared with the ones selected by individuals are also different. In general, this book is not only a reference book for agricultural study, but it also is an important instructional textbook for government officials to learn how to supervise the people’s production (Yi 1981).

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