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Co-evolution of fish and rice farming by Austroasiatic communities in the Neolithic Era and early documentation of aquaculture in China

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This paper is a review of the co-evolution of fish and rice farming about 10,000 years ago in the early Neolithic Era in China. China is often referred to as the origin of fish farming based on an oft cited document of Fan Li (448 BC – 536 BC) about 2,500 years ago. It is the earliest account of farming common carp (*Cyprinus carpio*) but its origin dates back much further. Oracle bone scripts of the Shang Dynasty (1,046 BC – 1,600 BC) are the earliest written record of fish farming in ponds. Farming common carp was prohibited in the Tang Dynasty (618 AD–907 AD) because the name of the fish, Li, was the same as that of an emperor, and this possibly led to farming Chinese carps in polyculture. There were increases in temperature and rainfall at the end of the last ice age in the Yangtze River Basin during the early Neolithic Era about 8,000 BC, drivers for subsequent development. A vast freshwater environment of inland lakes and swamps developed, with wetland plants including wild rice, as well as fish, bordered by deciduous forests and semi-arid grasslands on higher land. This enabled Austroasiatic people to gather wild foods, terrestrial and aquatic nuts as well as fish and rice. A mixed economy of hunting, gathering and fishing evolved into the co- evolution of fish and rice farming.

KEYWORDS

aquaculture, China, neolithic, carp, Fan Li, history

1 Introduction

Co-evolution of fish and rice farming was developed by Austroasiatic people during climate amelioration during the early Neolithic Era about 10,000 years ago in 8,000 BC at the end of the last ice age in the Holocene Epoch (Nakajima et al., 2010, 2019). The Neolithic Era was the first agricultural revolution in China (Bellwood, 2011, 2014; Nakamura, 2010; Zuo et al., 2024). Subsistence initially relied on gathering and harvesting freshwater fish and wild rice before the development of farming.

Fishing was the most important method of fish production in ancient times based on excavated fishing spears and hooks (Anon, 1961). The earliest written records in China are oracle bone inscriptions in the Shang Dynasty (1,600 BC to 1,046 BC) several millennia later than the Neolithic Era (Anon, 1961; Fei, 2017).

Rice farming involved an extension of shallow and wetland margin habitat (Fuller et al., 2009). Fish farming originated in co-evolution with rice farming in the Lower Yangtze River Basin about 10,000 BC (Chen and Jiang, 1997; Nakajima et al., 2008).

China is also the birthplace of different language families (Huang, 2022). Linguistic evidence suggests that Austroasiatic speaking, Neolithic early rice farming cultures, of the Yangtze River Basin migrated along the southern coast of China during the first half of the second millennium BC (Bellwood, 2011, 2014; Heggarty and Beresford-Jones, 2014; Higham, 2003). They were dispersed southwards by the expansion of Han Chinese from their homeland in the Yellow River Basin (Sidwell, 2013). Austroasiatic languages are spoken today across mainland East, South and Southeast Asia, by the majority of people in Cambodia and Vietnam and a minority in southern China (Sidwell, 2013). They are also spoken in many Pacific Island nations and Madagascar.

The first Chinese dynasty that left historical records, inscriptions on excavated oracle bones, was the Shang Dynasty (1,600 BC-1,046 BC) that settled along the Yellow River in eastern China during the Second Millennium BC (Anon, 1961). The oracle bone script of the Shang Dynasty were the oldest forms of Chinese writing found and the direct ancestor of modern Chinese characters.

The oracle bone scripts provide the earliest record of fish culture in ponds (Anon, 1961). Two of the oracle bones read 'to divine the rain period for fishing in the garden', and 'fishing in the garden in the eleventh moon' (Anon, 1961). The reference to catching fish in a vegetable garden could refer to farming of fish during the Shang Dynasty.

2 Methodology

The paper is a comprehensive review of literature on the evolution of fish farming in the early Neolithic Era during which it co-evolved with farming of rice. Some of the articles were obtained by the author from the British Library 30-50 years ago in the course of building a collection of early works documenting the history of aquaculture. He had access to the British Library as a British Government Technical Cooperation Officer seconded to the Asian Institute of Technology in Thailand. Most of those articles are not available online. The author's review of older sources has been supplemented by a review of more recent relevant publications.

The paper is a literature review synthesizing this body of work on the origins of aquaculture in China, organized as follows: 3.1, The Neolithic period in China; 3.2, Early settlements and subsistence; 3.3 Rice cultivation; 3.4 Fish culture; 3.5 Roles of common carp; 3.6 Common carp in Chinese culture; 3.7 Fan Li's document; 3.8 Han dynasty aquaculture; 4 Conclusion.

3 Literature review

3.1 The Neolithic era in China

There was an increase in temperature and summer monsoon rain between 9,000 and 8,000 BC during which the lower Yangtze River Basin changed into a vast freshwater environment of inland lakes and swamps with wetland plants including rice, bordered by deciduous forests and semi-arid grasslands (Zheng et al., 2009).

During the Neolithic Era in China there was a transition from hunting, gathering and fishing to farming rice and fish in the Yangtze River Basin between 7,500 and 4,000 BC. Subsistence in the Neolithic Era was initially reliant on gathering terrestrial tubers and nuts, aquatic nuts and wild rice, hunting wild animals and harvesting freshwater fish. It took another millennium to transform from harvesting wild rice to its cultivation (Nakamura, 2010).

The early Neolithic Era Austroasiatic Hemudu culture (8,000-6,400 BC) farmed rice in the lower Yangtze River Basin (Chi and Hung, 2014; Fei, 2017; Zuo et al., 2024). Two earlier cultures were the Nanzhuangtou culture in the Yellow River Basin (Yang et al., 2012) and the Pengtoushan culture in the middle Yangtze River Basin (Pei, 2013). Expansion of farming into southern China and into Southeast Asia by Austroasiatic people occurred from about 6,500 and 4,500 BC, respectively (Chi and Hung, 2008, 2014; Fei, 2017).

3.2 Early settlements and subsistence

Early Neolithic Era cultures in the alluvial lowlands of the lower Yangtze River Basin began to establish villages about 9,000 to 8,000 BC (Chen and Jiang, 1997; Chi and Hung, 2010). However, it took several millennia before agricultural systems with domesticated rice and prepared fields were developed (Nakamura, 2010; Zheng et al., 2009; Zuo et al., 2024). Early Neolithic Era cultures emerged from late Paleolithic hunter-gatherer societies but still relied primarily on gathering, hunting and fishing.

There was a mixed economy with major staples derived from open wetland and adjacent hill forest environments (Zheng et al., 2009). Subsistence was reliant initially on tubers and terrestrial nuts such as acorns (*Lithocarpus* and/or *Quercus* spp.), walnuts (*Juglans* spp.); fruit such as Chinese peach (*Prunus persica*) and Chinese plum (*Prunus salicina*) growing on highlands; aquatic nuts such as water chestnut (*Trapa bicornis*) and fox nut (*Euryale ferox*) gathered in lakes; and wild rice (*Oriza sativa*) (Chen and Jiang, 1997; Chi and Hung, 2008, 2010; Fuller and Qin, 2010; Nakamura, 2010).

Wild terrestrial and amphibious fauna hunted included mammals water buffalo (*Bubalus bubalis*), deer (*Hydropotes inermis*) and pig (*Sus* sp.); reptiles included terrapins (*Ocadia sinensis*) and Chinese alligator (*Aligator sinensis*); and birds such as duck (*Anas platyrhynchos*), swan goose (*Anser cygnoides*), and Japanese crane (*Grus japonensis*) (Zheng et al., 2009).

There was extensive exploitation of freshwater fish (Fuller and Qin, 2010). Fish caught included crucian carp (*Carassius carassius*),

goldfish (*Carassius auratus*), and northern snakehead (*Channa argus*), and many other species (Zheng et al., 2009).

The lower Yangtze River Basin probably had one of the densest populations in the world by 5,000 BC (Bellwood, 2014).

3.3 Rice cultivation

The origin of rice farming is well documented (Fuller et al., 2009; Fuller et al., 2009; Zhong et al., 2007). A shift from harvesting wild rice to its domestication began in the lower Yangtze River basin about 10,000 years ago in 8000 BC and lasted until 2,000 BC (Zheng et al., 2009; Ma et al., 2018).

The oldest known rice fields with surrounding dykes, ditches and channels for water control were developed between 5,500 and 4,500 BC in the Hemudu culture period (Fuller and Qin, 2010; Zheng et al., 2009). The Hemudu culture existed from 5,500 BC to 3,800 BC during the Neolithic period to the south of Hangzhou Bay in Zhejiang Province in modern day China (Nakajima et al., 2010; Ma et al., 2018).

Rice cultivation and associated organizational changes in societies followed and were spread throughout southern China by 6,000-5,500 BC and reached Thailand and Vietnam in Southeast Asia by 4,000-3,000 BC (Chi and Hung, 2008).

3.4 Fish culture

The origin of farming fish is less well documented than that of rice (Nakajima et al., 2010, 2019; Harland, 2019). Farming fish co-evolved with rice cultivation in the early Neolithic Era about 8,000 years ago in the Lower Yangtze River Basin, from about 6,000 BC (Harland, 2019; Nakajima et al., 2008, 2019). Clay models of a system including fish farming were found in graves of the Later Han Dynasty (25-AD-220 AD) in several regions of China (Bray, 1984). Farmers dug small ponds to irrigate rice fields as well as to farm aquatic plants and fish. The Han Government encouraged a 'march to the tropics', causing farmers from the north to settle in the Yangtze River Basin in central China, and in southern China.

Farming common carp (*Cyprinus carpio*) and crucian carp was present in the Early Neolithic Era in China by about 6,000 BC. The body-length distribution of excavated fish bones was bimodal with both mature fish of 35-40 cm and immature fish of 150-200 mm indicative of carp farming. Fish were caught during the spawning season for human food and some were released into confined waters where they spawned naturally and their offspring grew by feeding on available resources (Nakajima et al. (2019).

Three stages of Neolithic fish farming development were hypothesized (Nakajima et al., 2019):

Stage 1: marshy areas where fish gathered during the spawning season were fished.

Stage 2: rice was cultivated in irrigated rice fields with water levels and circulation controlled so that fish could spawn and juveniles could be harvested later.

Stage 3: spawning beds were constructed to control fish reproduction and rice fields or ponds constructed to manage juvenile fish.

The development of rice fields with water management evolved later than that of the rice plant itself, so more efficient co-farming of fish and rice may have developed later than the earliest Neolithic Era.

3.5 Roles of common carp

Fish farming was a more convenient way of obtaining fish for food than harvesting from nature. Fish was also used as a gift in ancient times (Anon, 1961). Confucius (551 BC-479 BC) named his son Li, which means carp, symbolizing good fortune and prosperity, after the common carp presented to him as a gift by Chiu Kung, a nobleman of the early Zhou Dynasty (Anon, 1973). Fish were used as gifts given by people to officials, as well as being given as gifts by lords to their subjects. Fish were also used as a sacrificial item, especially in ancestral temples. Fishponds also provided a scenic site for relaxation.

Farming common carp had become widespread in the lower Yangtze River basin by the time of the first millennium BC. Other species of wild fish could have been used to stock ponds and some might have thrived and grown but none could be bred in captivity.

3.6 Common carp in Chinese culture

There is a long tradition of common carp in Chinese culture and literature (Burkhardt, 1959; Lindqvist, 1991; Williams, 1974).

In Chinese mythology, if the fish could climb a waterfall called the Dragon Gate at Henan on the Yellow River they would be transformed into dragons. Fish gathered every year in vast numbers in a pool at the foot of the falls but it used to be said that only 71 fish could make the climb as after the first fish succeeded the rain would begin to fall so that the flooded river prevented more fish from climbing the waterfall. The Dragon Gate was said to have been created after the flood by the god-emperor Yu, who split a mountain blocking the path of the Yellow River. Many other waterfalls in China are also called Dragon Gate, with much the same said about them.

It was a common saying that a student taking an examination was like a carp attempting to leap the Dragon Gate. The jumping fish proverbial idiom also symbolized a sudden uplifting in social status in society or favor with a royal or noble family, perhaps through marriage, but in particular through success in the imperial examination. It is used to encourage students to achieve success through hard work and perseverance.

The carp has been a most popular theme in Chinese as well as Japanese paintings, usually colored in gold or pink, shimmering with an auspicious tone.

3.7 Fan Li's document

Fan Li was a politician who wrote a single page document on farming common carp in 460 BC in the Zhou Dynasty (1,046 BC-256 BC), the earliest written account of fish farming (Anon, 1986; Lee, 2021). The original document had been lost but fortunately

recorded in a subsequent work, although doubts remain whether the transcription had been complete (Anon, 1961). It became the main reference for all subsequent literature on farming fish for over two millennia with few additions until publication of *The Complete Book of Agricultural Management* by Hsu Kuang Chi (1562-1633), a Chinese agronomist, astronomer, mathematician and politician, in which polyculture of Chinese carps was also mentioned.

There were several reasons for the particular style of pond construction (Anon, 1961), as set out by Fan Li. Nine islets and 8 six chih (1 chih = 0.358 meters) deep areas in a two chih deep pond were intended to satisfy the ecological requirements of the fish by enabling them to move around freely as in a river or lake and therefore reducing the effect of the limited space in the pond as well as providing resting and hiding places as temperatures rise and fall. It also made the pond suitable for conditioning brood stock, with shallow areas for spawning, hatching fertilized eggs and nursing young fish. A length of three chih would approximate 1.1 m and a body weight of 3 kg, a good size for brood stock.

Despite its limited script, the document showed the experience of common carp culture at the time even though the units do not correspond to those of today's metric system of measurement. It indicated the high profit of common carp farming although costs including types of feed were not given. It was influenced by superstitious traditions of the time such as the presence of a turtle would prevent the fish from flying away, although a fairy dragon would let fish fly away.

3.8 Han Dynasty fish farming

In the Han Dynasty (206 BC-220 AD) fish ponds were constructed according to the method specified by Fan Li who developed fish ponds on the southern shore of Hangzhou Bay in Zhejiang Province. Fish farming was also developed along the shore of a lake, Tai Hu, in Jiangsu Province (Anon, 1961).

King Wei of the state of Qi during the Warring States period/Eastern Zhou (475 BC-221 BC) asked Fan Li for his methods to construct fish ponds in his garden in Shandong Province as he had heard that Fan Li was wealthy (Anon, 1961; Lee, 2021). He asked what was the secret and Fan Li replied fish farming. Fan Li proceeded to explain fish farming as follows.

Build a six mu (1 mu = 667 square meters) fishpond with nine islets and plant aquatic macrophytes so that fish swimming around would feel as if in natural rivers and lakes. Collect and stock the pond with 20 gravid and four large male carp during the early part of the second moon (about March today) for the fish to spawn. During the fourth moon introduce one turtle, the sixth month two turtles and the eighth month three turtles into the pond. The turtles are heavenly guards against flying predators. By the second moon of the following year, 15,000 fish of one chih length, 45,000 fish of two chih length and 10,000 fish of three chih length, could be harvested with a value of 1,250,000 coins for the entire crop. The following year, 100,000 carp of one chih, 50,000 of two chih, 50,000 of three chih and 40,000 of four chih could be harvested. Keep 2,000 carp two chih long as broodstock and sell the remainder for 5,150,000 coins. The increase in income in the following year would be enormous.

Following the advice to construct and stock a fishpond, King Wei earned more than 300,000 coins at the end of the first year and handsome profits in subsequent years. Fish culture became widespread in the second millennium BC. Other species of wild fish could have been used to stock ponds and some might have thrived and grown but none could have bred in captivity. Carp was also raised because it was fast growing, easy to raise and not cannibalistic.

An addendum that appeared in the Ching but not in the Ming version gave details of collecting carp from nature (Lee, 2021). Carp with a length of three chih are obtained only in large lakes and rivers. Starting with small fish would take too long for them to mature. If starting with spawn, collect it from the banks of lakes and rivers where large carp gather. Collect the mud containing carp eggs at the water's edge and spread it on the bottom of the fish pond where the eggs will hatch and grow into large carp in two years.

3.9 Tang Dynasty fish farming

The founder of the Tang dynasty is Li Yuan, the Emperor Gao Zhu. A stage in the evolution of Chinese fish farming was the requirement by law for fishers in the Tang Dynasty (618 AD-907 AD) to release common carp if captured as the name of the fish was the same as that of Li Yuan (Anon, 1961). A garden by a lake, Tai Hu, near Wuxi is named in his honor. Farming common carp culture was also forbidden. Literature from the Warring States Period of the Zhou Dynasty (475 BC-221 BC) to the Sui Dynasty (581-618 AD) mainly refers to common carp. The deterrence of the culture of common carp possibly led to the culture of other species such as the Chinese carps and the origin of polyculture.

There are records of the collection and transportation of Chinese carp fry from the Sung dynasty (960 AD-1,276 AD) and detailed accounts of carp polyculture from the Ming dynasty from 1,368-1,644 (Anon, 1961). Fish fry fisheries and fish fry culture were also documented in the *Four Books of Agriculture and Gardening* and the *Complete Book of Agricultural Management*, published in the 17th Century.

The earliest accounts in European languages of Chinese fish farming are those of Portuguese and Spanish Jesuits in China in the 16th century (Pereira, 1569). They observed an abundance of fish throughout the interior of the country, mostly from fishponds belonging to magistrates in the principal cities who had kitchen gardens with fishponds.

4 Conclusion

The review provides a comprehensive and documented synthesis of the origins and early history of fish farming in China, drawing from archaeological, historical, and linguistic evidence.

Austroasiatic people of the Hemudu culture in the Lower Yangtze River Basin, central China, gathered wild food, terrestrial and aquatic nuts, fish and rice in the early Neolithic Era from about 8,000 BC.

The earliest written account of fish farming, that of common carp by Fan Li in 460 BC, indicated that it had become widespread much later in the first millennium BC. Polyculture of common carp and Chinese carps may have been developed because the name of the emperor at that time was Li, the same as that of common carp.

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PE: Conceptualization, Data curation, Formal analysis, Writing – original draft.

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References

- Anon (1961). *Science of the Culture of Freshwater Fish Species in China* (Beijing: Science Publications). Translation by IDRC in 1981 of the original Chinese text, second edition.
- Anon (1973). *The pictures about Confucius life* (Shandong, China: Commission of the Culture Relics of Shandong, Qufu Administrative, Shandong Friendship Press), 54.
- Anon (1986). “A brief introduction of Fan Li on pisciculture,” in *Chinese, English, Russian, French and Spanish* (Chinese Fishery History Research Association, Beijing), 103.
- Bellwood, P. (2011). The checkered prehistory of rice movement southwards as a domesticated cereal—from the Yangzi to the Equator. *Rice* 4, 93–103. doi: 10.1007/s12284-011-9068-9
- Bellwood, P. (2014). “10. Neolithic migrations: food production and population expansion,” in *The global prehistory of human migration*. Ed. P. Bellwood (Hoboken, New Jersey, USA: Wiley, Blackwell), 230–247.
- Bray, F. (1984). “Part 2: agriculture,” in *Science and Civilisation in China*, vol. 6. Ed. J. Needham (Cambridge University Press, Cambridge, England), 724 p.
- Burkhardt, V. R. (1959). *Chinese creeds and customs* Vol. 2 (Hong Kong: The South China Morning Post, Ltd), 212 p.
- Chen, B. Z., and Jiang, Q. H. (1997). Antiquity of the earliest cultivated rice in central China and its implications. *Economic Bot.* 51, 307–310. doi: 10.1007/BF02862100
- Chi, Z., and Hung, H. C. (2008). The neolithic of southern China—origin, development, and dispersal. *Asian Perspect.* 47, 299–329. doi: 10.1353/asi.0.0004
- Chi, Z., and Hung, H. C. (2010). The emergence of agriculture in southern China. *Antiquity* 84, 11–25. doi: 10.1017/S0003598X00099737
- Chi, Z., and Hung, H. C. (2014). “26. Eastern Asia archaeology,” in *The Global Prehistory of Human Migration*. Ed. P. Bellwood (Hoboken, New Jersey, USA: Wiley, Blackwell), 534–553.
- Fei, X. T. (2017). The formation and development of the Chinese nation with multi-ethnic groups. *Int. J. Anthropology Ethnology* 1, 1–31. doi: 10.1186/s41257-017-0001-z
- Fuller, D. Q., Qin, L., Zheng, Y., Zhao, Z., Chen, X., Hosoya, L. A., et al. (2009). The domestication process and domestication rate in rice: spikelet bases from the Lower Yangtze. *Science* 323, 1607–1610. doi: 10.1126/science.1166605
- Fuller, D. Q., and Qin, L. (2010). Declining oaks, increasing artistry, and cultivating rice: the environmental and social context of the emergence of farming in the Lower Yangtze Region. *Environ. Archaeology* 15, 139–159. doi: 10.1179/146141010X12640787648531
- Harland, J. (2019). The origins of aquaculture. *Nat. Ecol. Evol.* 3, 1378–1379. doi: 10.1038/s41559-019-0966-3
- Heggarty, P., and Beresford-Jones, D. (2014). “Farming-language dispersals: a worldwide survey,” in *Encyclopedia of Global Archaeology*. Ed. C. Smith (Springer, New York), 2731–2739.
- Higham, C. (2003). “Chapter 18 languages and farming dispersals: austroasiatic languages and rice cultivation,” in *Examining the farming/language dispersal hypothesis*. Eds. P. Bellwood and C. Renfrew (Cambridge, UK: Cambridge University Press), 223–232.
- Huang, X. F. (2022). Genomic insights into the demographic history of the southern Chinese. *Front. Ecol. Evol.* 10, 1–18. doi: 10.3389/fevo.2022.853391

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- Lee, F. (2021). *Appendix 1 and 2. Excerpts from Chinese fish culture* (Solomons, Maryland, USA: Contribution No. 459, Chesapeake Biological Laboratory, University of Maryland), 3.
- Lindqvist, C. (1991). “China empire of living symbols,” in *Lifelong Books* (Da capo Press, Cambridge, USA), 424.
- Ma, Y. C., Yang, X. Y., Huan, X., Gao, Y., Wang, W., Li, Z., et al. (2018). Multiple indicators of rice remains and the process of rice domestication: A case study in the lower Yangtze River region, China. *PLoS One* 13, 1–14. doi: 10.1371/journal.pone.0208104
- Nakajima, T., Nakajima, M., Mizuno, T., Sun, G. -P., He, S. -P., and Liu, H. -Z. (2010). On the pharyngeal tooth remains of crucian and common carp from the Neolithic Tianluoshan site, Zhejiang Province, China, with remarks on the relationship between freshwater fishing and rice cultivation in the Neolithic Age. *Int. J. Osteoarchaeology* 2, 294–304. doi: 10.1002/oa.1206
- Nakajima, T., Hudson, M. J., Uchiyama, J., Makibayashi, K., Zhang, J., et al. (2019). Common carp aquaculture in Neolithic China dates back 8,000 years. *Nat. Ecol. Evol.* 3, 1415–1418. doi: 10.1038/s41559-019-0974-3
- Nakajima, T., Nakajima, M., Mizuno, T., and Sun, G. P. (2008). Evidence for fish cultivation during the Yayoi Period in western Japan. *Int. J. Osteoarchaeology* 2, 127–134. doi: 10.1002/oa.1005
- Nakamura, S. (2010). The origin of rice cultivation in the Lower Yangtze Region, China. *Archaeological Anthropological Sci.* 2, 107–113. doi: 10.1007/s12520-010-0033-0
- Pei, A. P. (2013). “The pengtoushan culture in the middle Yangzi river valley,” in *A.P. A Companion to Chinese Archaeology* (Oxford, UK: Blackwell Publishing Ltd).
- Pereira, G. (1569). Text of Galeote Pereira, p.1-45., In: C. R. Boxer (ed.), *South China in the Sixteenth Century*. (Bangkok: Bibliotheca Orientalis, Orchid Press), 388 pp.
- Sidwell, P. (2013). “33. Southeast Asian mainland: linguistic history,” in *The Global Prehistory of Human Migration*. Ed. P. Bellwood (Hoboken, New Jersey, USA: Wiley, Blackwell), 655–676.
- Williams, C. A. S. (1974). *Chinese Symbolism & Art Motifs* (Singapore: Tuttle Publishing), 475.
- Yang, X. Y., Wan, Z., Perry, L., Lu, H., Wang, Q., Zhao, C., et al. (2012). Early millet use in northern China. *Proc. Natl. Acad. Sci.* 109, 3726–3730. doi: 10.1073/pnas.1115430109
- Zheng, Y. F., Guoping, S., Ling, Q., Chunhai, L., Xiaohong, W., Xugao, C., et al. (2009). Rice fields and modes of rice cultivation between 5000 and 2500 BC in east China. *J. Archaeological Sci.* 36, 2609–2616. doi: 10.1016/j.jas.2009.09.026
- Zhong, Y., Chen, Z., Innes, J. B., Chen, C., Wang, Z., and Wang, H. (2007). Fire and flood management of coastal swamp enabled first rice paddy cultivation in east China. *Nature* 449, 459–462. doi: 10.1038/nature06135
- Zuo, X. X., Lu, H., Jiang, L., Zhang, J., Yang, X., Huan, X., et al. (2024). Dating rice remains through phytolith carbon-14 study reveals domestication at the beginning of the Holocene. *Proc. Natl. Acad. Sci.* 114, 6486–6491. doi: 10.1073/pnas.1704304114