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SHOWCASES

When the natural pendulum swings between drought and flood, a bifunctional natural drainage system safeguards a mountain village's water security incessantly for centuries

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Abstract
This article showcases a long-standing water-secure village in a mountain area in China and its water safeguard system. For centuries, the village has been shielded from the adverse impacts of drought and flood and continues to be a water-secure oasis amid the water-insecure environs. The safeguard for its enduring water security is a one-of-a-kind bifunctional natural drainage system (NDS) of green infrastructures that prevents flood and harvests stormwater simultaneously during storm events and releases the stored water for subsequent, year-round use. Built by the villagers upon two ecologically wise (i.e., ecophronetic) ideas—*working with the duality of stormwater* and *building with nature*, the NDS is characterized by double highs and triple lows—high effectiveness, high robustness, low tech, low maintenance, and low impact. This extraordinary feat of socio-ecological practice is as such a strong candidate for the recognition as a time-honored example of nature-based solutions.

Keywords Yujiacun Village (于家村) · Water security · Natural drainage systems (NDS) · Nature-based solutions (NBS) · The duality of stormwater · Building with nature · Ecophronesis (ecological practical wisdom)

1 A water-secure village in a water-insecure mountain area

In the Taihang Mountain region of western Hebei Province, China, there is an age-old village named Yujiacun (Fig. 1). It was founded circa 1486 on a desert tract among barren, rocky hills (Sun 2014, p.12; Wei and Luo 2009, pp.61–62). The founder Yu Youdao (于有道) was a displaced grandson of Yu Qian (于谦, 1398–1457), the well-respected national hero in the Ming Dynasty (1368–1644) and an innocent victim of a corrupted frame-up (Sun 2014, p.12; Wei and Luo 2009, pp.61–62; Zhao and Che 2020, p.65).[1] Over the past 500 years, this small stretch of erstwhile desolate land (approx. 23 ha) has evolved into the permanent home of an extended Yu family of 1600 people (Sun 2014, p.11; Wei and Luo 2009, p.62; Zhao and Che 2020, p.65), nestling in a mosaic of terraced farmlands and hilly scrublands (Fig. 2; Sun 2014, p.29). Its name *Yujiacun Village* in Chinese, 于家村, literally means "the village of the Yu family," making this identifying characteristic hard if not impossible to miss.

Yujiacun Village is known for being a thriving and inviting mountain village whose inhabitants take both delight and pride in its sustained *water security* (Zhao 2008, p.23; Zhao et al. 2018; Zhao and Che 2020, pp.65–78). Water security here refers to a state of human settlement under which the inhabitants have both *the assurance* of adequate, sustained, and accessible quality water supply and *the protection* against

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[1] The Chinese historian Zhang Haiying (张海英) provides a succinct narrative of Yu Qian's contributions to the nation and his tragic death (Zhang 2015, pp.83–88).

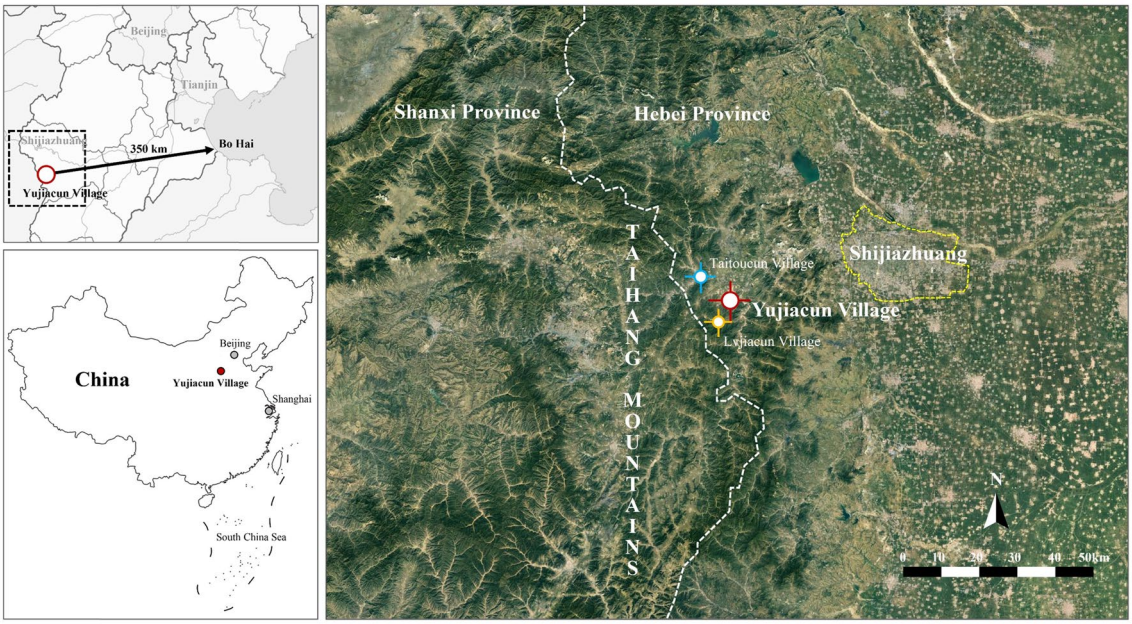

Fig. 1 The location of Yujiacun Village (Shijiazhuang is the capital city of Hebei Province; Lvjiacun Village (6 km southwest) and Taitoucun Village (11 km northwest) will be mentioned in subsection 1.2; the topographic image is from Google Earth (https://earth.google.com/web/@37.90453716,113.90799853,764.06175731a,207302.89326154d,35y,0h,0t,0r?utm_source=earth7&utm_campaign=vine&hl, accessed 12/06/2021)

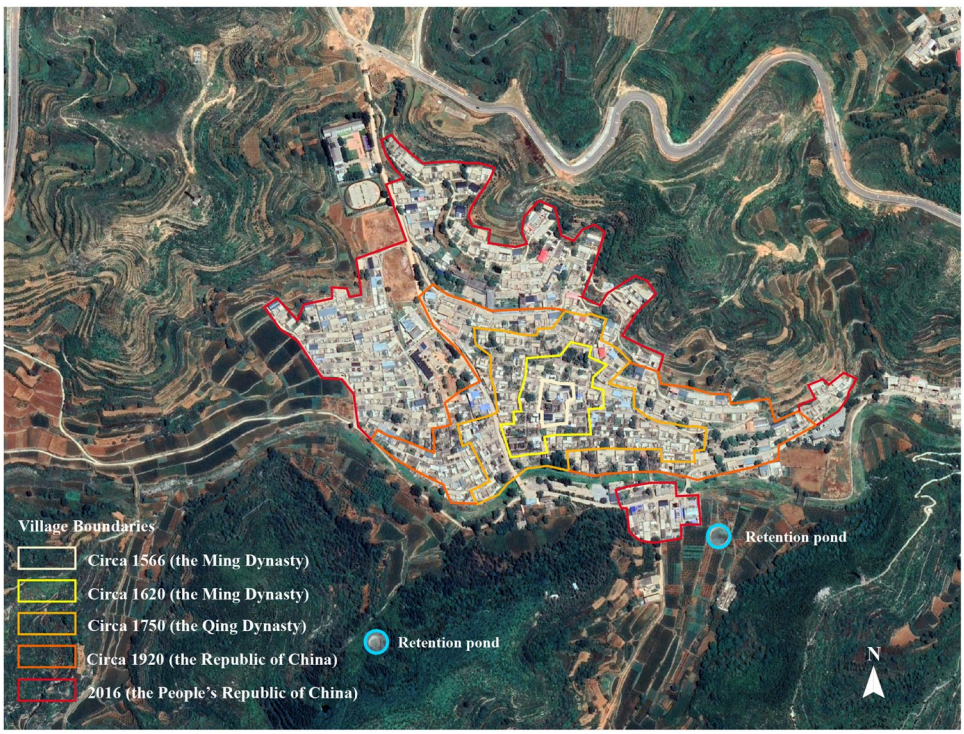

Fig. 2 Yujiacun Village: its evolution and present environs. [**Note**: The village boundaries are based on Figs. 4–8 in Sun (2014, p.19) and a 2016 field survey by Han Chao (韩超), an erstwhile graduate student at Jilin Jianzhu University, China; the topographic image is from Google Earth (https://earth.google.com/web/@38.17053722,114.02710776,-90955.90581979a,96487.17279193d,35y,-0.06631696h,15.63092628t,359.999r?utm_source=earth7&utm_campaign=vine&hl, accessed 12/06/2021)]

impacts of such water-related phenomena as water-borne pollution, drought, flood, sea level rise, soil erosion, landslide, and mudflow.[2] Yet, what makes the villagers even more proud and the village more prominent is the paradox that it is an oasis of sustained water security in the environs of intrinsic water insecurity (Zhao et al. 2018; Zhao and Che 2020, pp.65–78).

1.1 The environs of alternating droughts and floods

For two specific reasons, the area Yujiacun Village resides in is by nature water-insecure (Huang 1730/1976, pp.152–153; Zhao et al. 2018, p.42; Zhao and Che 2020, pp.67–68). The first is the lack of surface water and groundwater resources. Because of the temperate monsoon climate and inland location (approx. 350 km from the nearest seashore, see Fig. 1), the area is a semiarid place with an annual precipitation of 450 mm, almost all of which falls as downpours in July and August[3]; without year-round feeding from either perpetual snow of the mountain peaks or perennial springs, creeks are small and unexceptionally seasonal; lying under thick layers of nonporous rock, areal aquifers are deep (400+ meters) and hard for groundwater extraction. The second reason for the area's intrinsic water insecurity is the high occurrence of flood. Monsoonal stormwater in July and August readily forms instantaneous surface runoff on the surrounding rocky hills, which quickly runs downhill to the bottom of the drainage basin without recharging groundwater sources; along the way, some of the runoff deluges the river terrace where the village presently resides on (Fig. 2).[4]

Manifesting this intrinsic water insecurity, the natural pendulum in the area swings between drought and flood with the absence and presence of precipitation rigorously to the extent that "whenever there is no precipitation, there is a drought; whenever there is a precipitation, there is a flood" (Zhao et al. 2018, p.42; Zhao and Che 2020, p.68).[5] For any human settlement to survive in such a water-insecure area, a transformation toward water security is a prerequisite.

Yujiacun Village is indisputably a beneficiary of such transformation.

1.2 A water-secure oasis, rain or shine

Thanks to a remarkable storm drainage system, the village has been a water-secure oasis amid alternating droughts and floods for centuries, and still is.

To all the villagers, the village provides the year-round assurance of adequate, sustained, and accessible water supply. The assurance comes from its 1000-plus underground cisterns (Wei and Luo 2009, p.63; Zhao 2008, p.23; Zhao and Che 2020, pp.70–74; Zhao et al. 2018, p.43). These cisterns are of different sizes (20–40 m^3) and can each hold 20,000–40,000 L of water (Fig. 3). As part of a village-wide storm drainage system, they harvest and store rainwater in the summer (occasionally snow water in the winter) and supply the water to the villagers and their domestic animals throughout the year, rain or shine. Situated in every corner of the village, they are readily accessible. Over the past 500 years, the number and capacity of underground cisterns have increased significantly to accommodate the village's growth. As a reliable source of potable water, they continue to be in service even with the addition of new water supplies—two inter-basin water diversion canals in the 1950s

[2] **[1]** Whence did our conception of water security in the context of human settlement come? We drew from two much-cited, broad definitions. UN-Water, the United Nations' inter-agency coordination mechanism for all water-related issues (United Nations University 2013), defines water security as "The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water 2013). Similarly, leading authors of water development and management David Grey and Claudia Sadoff (2007, pp.547–548) define water security as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies". **[2]** Throughout this article, we use the term *water security*, its antithesis *water insecurity*, and their respective corresponding adjectives *water-secure* and *water-insecure* to describe human settlements as well as places where human settlements reside in. This usage is in line with that in Grey and Sadoff (2007). **[3]** For a recent critical review of the conceptions of water security and the challenges to the human endeavor of achieving and sustaining water security, see Staddon and Scott (2018).

[3] **[1]** These "regional heavy precipitation events (RHPEs)" (Wu et al 2019, p.414) in July and August are results of the northward movement of the East Asian summer monsoon rain belt, which brings water vapor from the South China Sea and tropical western Pacific to inland areas of China (*Ibid.*, p.420, p.418, p.424). **[2]** A semiarid area typically has an annual precipitation between 250 and 500 mm (Merriam-Webster 2021; Zhang and Li 1999, p.231). For a review of different indices used in delineating semiarid regions in China, see Zhang and Li (1999).

[4] **[1]** A river terrace is a "bench or step that extends along the side of a valley and represents a former level of the valley floor" (The Editors of Encyclopaedia Britannica 1998). As shown in Fig. 2, all the area within the 1750 boundary is on the river terrace, while later development all goes uphill. **[2]** A flood-related phenomenon is soil erosion in the area—when flowing over patches of scrub on the slopes, the downhill runoff easily washes away barren soil (Zhao and Che 2020, pp.68–70). Since this aspect of intrinsic water insecurity in the area is not the focus of our article, we refer readers to Fig. 2 in which the terraced farmlands and planted trees on the surrounding hills are effective measures villagers used to prevent soil erosion.

[5] The quote is a translation of the Chinese phrase "无雨是旱,有雨成涝", the characterization of the alternating drought–flood situation in the area by the authors of Zhao et al. (2018, p.42).

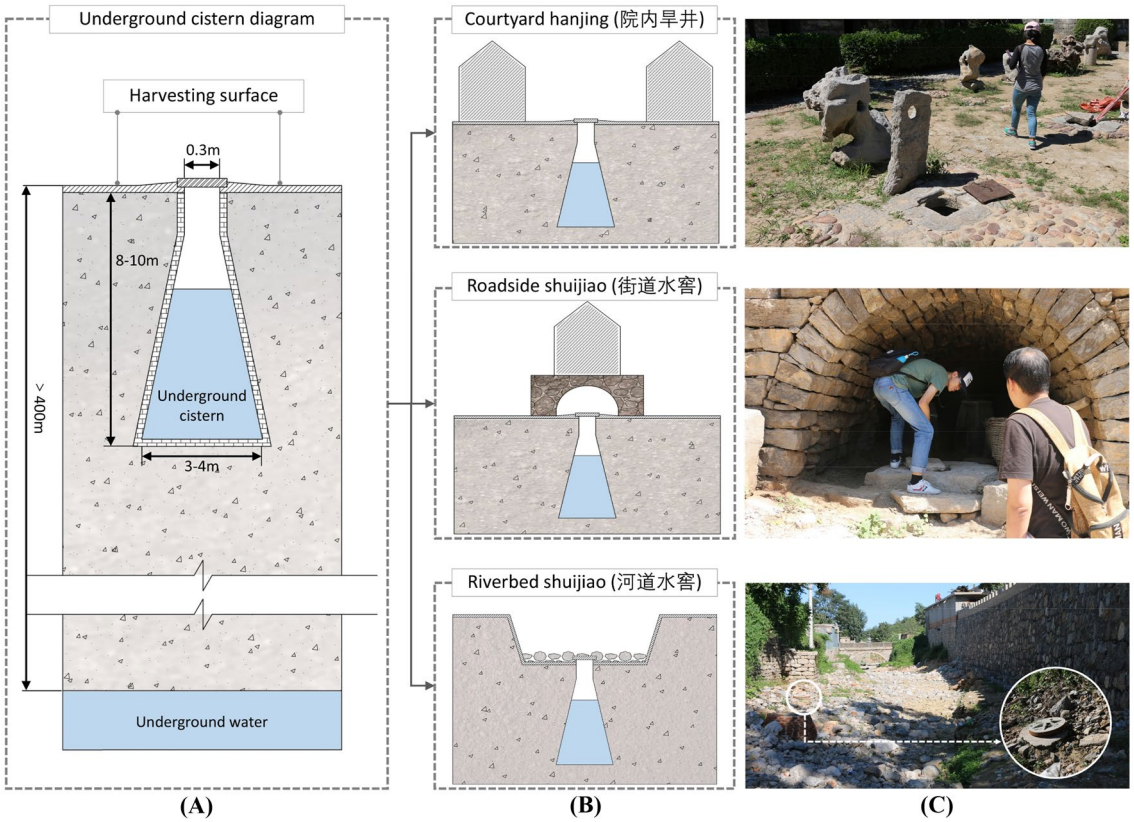

Fig. 3 Underground cistern diagram (**A**), diagrams of three types of underground cisterns—courtyard hanjing (院内旱井), roadside shuijiao (街道水窖), riverbed shuijiao (河道水窖) (**B**), and photographs taken at the cistern sites (**C**) by Han Chao on August 27, 2016; use with permission. [**Note**: To prevent leakage and protect water quality, the walls and bottom of each cistern are built with stones from the surrounding mountains and the joints between stones filled with self-made mortar; the three types of underground cisterns are from Zhao et al (2018, p.43), so are their Chinese names with one exception: we use courtyard hanjing (院内旱井) in place of courtyard shuijiao (院内水窖) as a result of rectification]

(Liang et al. 2012) and five drilled wells since the 1970s (Han 2021).[6]

Along with the year-round assurance of water supply is the seasonal shield against the risk of flooding. The village provides this protection to the villagers and their properties through its storm drainage system (Zhao and Che 2020, pp.70–74; Zhao et al. 2018, p.43). The system, as we will elucidate in the next section, effectively reduces the volume and regulates the direction and velocity of stormwater runoff, so much so that in the village, "there is no flood when it rains heavy; there is no runoff when it rains light" (Zhao and Che 2020, p.72; Zhao et al. 2018, p.43).[7] It is therefore no wonder that, throughout its 500-year history, the village has survived many devastating storms without being awash. In the 1-in-100-year high-intensity downpour on July 19, 2016, for a most recent example, more than 450 mm (the average annual amount) of precipitation poured into the area over a period of 20 h. While two adjacent villages [i.e., Lvjiacun Village (6 km southwest) and Taitoucun Village (11 km northwest), see Fig. 1] were overwhelmed by flash floods, Yujiacun Village remained unscathed (Zhao and Che 2020, pp.67–68; Fig. 4).

[6] **[1]** "Drilled wells are constructed by percussion or rotary-drilling machines. Drilled wells can be thousands of feet [i.e., hundreds of meters in the metric system] deep and require the installation of casing. Drilled wells have a lower risk of contamination due to their depth and use of continuous casing" (US–EPA 2021). **[2]** The underground cisterns in the village have also been used to store water from the drilled wells in the recent years (Han 2021).

[7] The quote is a translation of the Chinese phrase "大雨不积水, 小雨不湿鞋" used by the villagers in describing the performance of the village's storm drainage system. It was cited by Zhao and Che (2020, p.72) and Zhao et al. (2018, p.43).

Fig. 4 A juxtaposition of photographs taken in the aftermath of the 100-year storm on July 19, 2016. [**Note**: While the adjacent Lvjiacun Village (6 km southwest of Yujiacun Village, marked on the topographic image in Fig. 1) was badly flooded (left), Yujiacun Village (right) remained unscathed. Photos are from Figs. 2–37 in Zhao and Che (2020, p.68), use with permission]

2 A storm drainage system that feeds two birds with one scone[8]

The storm drainage system that safeguards the village's water security is a natural drainage system (NDS). An NDS is a network of nature-inspired and locally attuned green infrastructures (GIs) that meets the water security needs of the people in a particular place; it collects, conveys, harvests stormwater runoffs, and makes the stored stormwater available for subsequent use.[9] The NDS in Yujiacun Village (the Yujiacun NDS, henceforth) is a one-of-a-kind bifunctional NDS that meets the villagers' needs for both water supply and flood prevention with its dual functionality.

2.1 The bifunctional NDS: its components, spatial layout, and dual functionality

The Yujiacun NDS consists of two distinct yet complementary subsystems: the stormwater harvesting system and runoff controlling system. Each of them performs a particular water security function and cooperates with the other through a delicate spatial layout; together, they keep the village water-secure.

The stormwater harvesting system comprises the 1000-plus underground cisterns aforementioned; it captures and stores stormwater runoff and releases the treated water for subsequent, year-round use. The cisterns spread throughout the village—in the courtyard of each house, along the village streets, and on the riverbed of the seasonal creek at the bottom of the drainage basin—making stormwater harvesting more available and subsequent use more accessible (Fig. 5A).[10] The runoff controlling system comprises sloped permeable streets, roadside open (i.e., uncovered) channels, and storm drains. The streets and accompanying roadside open channels fall into two general categories: primary streets that extend from the north to south and are somewhat perpendicular to the seasonal creek at the bottom of the drainage basin, and secondary streets that extend from the east to west and parallel to the seasonal creek (Fig. 5A). Storm drains are in the courtyards of villagers' houses and connected to the open

[8] To express figuratively the idea *accomplish two things (or achieve two goals) with one action (one instrument, means)*, we use "feed two birds with one scone." This is an animal-friendly version of the idiom "kill two birds with one stone", as recommended by PETA (People for the Ethical Treatment of Animals) (PETA 2020). Putting the idiom and its animal-friendly variant in the Chinese-language context, their counterparts are 一石二鸟 and 一食二鸟, respectively.

[9] **[1]** There are four sources of inspiration for our NDS definition. First and foremost, the storm drainage system in Yujiacun Village itself—its underlying ideas, components, characteristics, and functions. These will be elucidated in this and next section. Second, the NDS definition by Seattle Public Utilities (2018), in which an NDS is defined as a system of engineered facilities that mimics nature to slow, reduce, clean, and use stormwater runoff close to its source (e.g., streets, rooftops and parking lots). Third, the stormwater management concept by Holm et al. (2014) which advocates a storm drainage system that uses GIs to "keep stormwater close to where it falls", "keep it clean, slow it down, soak it in." Fourth, the sustainable drainage systems by Grant (2016, pp.10–11) "which mimic natural drainage by intercepting, detaining, attenuating and infiltrating rainwater and promoting evapotranspiration through the use of natural features, thereby keeping rainwater out of the sewers." **[2]** In the NDS definition, we use the contemporary nomenclature *green infrastructures* as an umbrella term for the NDS components whether they are built-with-nature by humans (e.g., sloped permeable streets, underground cisterns, retention ponds) or straightly built-by-nature (e.g., seasonal creeks). As such, the adjective "green" here means "tending to preserve environmental quality (as by being recyclable, biodegradable, or nonpolluting)" (Merriam-Webster 2022). For a succinct review of the GIs concepts, see La Rosa et al (2021, p.330). The idea of building with nature will be discussed in subsection 3.2.

[10] Historically, retention ponds (Chinese: 涝池, Pinyin: laochi) played an important role in both runoff control and stormwater harvest and served as a major drinking water supply (Han 2021; Jingxing County Government 2020; Zhao and Che 2020, p.70, p.73). They were gradually replaced by underground cisterns which are more advantageous in playing those roles. At the time of this writing, there are two remaining retention ponds that are located on the hills south of the village for irrigation purpose (marked on Fig. 2). For a definition of retention ponds and a useful comparison with detention ponds (旱池, hanchi), see Laramie County Conservation District (2016).

channels alongside secondary streets (shown in the close-up illustration in Fig. 5B). Together, they form a three-leveled stormwater conveyance network that regulates the movement of stormwater runoff to reduce flood risk.

2.2 Flood prevention and stormwater harvesting during a storm event

The following typical scenario illustrates how the two subsystems of the Yujiacun NDS operate synergically to reduce flood risk and harvest stormwater during a "typical" storm event. It draws on previous field surveys (Zhao and Che 2020, pp.70–74; Zhao et al. 2018, p.43) and is further verified through recent interviews with the villagers (Han 2021).

During a storm event, as shown in Fig. 6, the runoff controlling system and the stormwater harvesting system cooperate to "keep stormwater close to where it falls," to "soak it in" (Holm et al. 2014), and to store it up—the sloped permeable streets and the underground cisterns help reduce the volume of stormwater runoff through soil infiltration and stormwater harvesting, respectively. The runoff controlling system, through its three-leveled stormwater conveyance network, collects stormwater falling onto it and runoff feeding into it and effectively transports them to the seasonal creek outside the village. The conveyance network also helps avoid the potential property damage the stormwater runoff may cause—it regulates the direction of stormwater runoff and slows down flow velocity through a delicate spatial configuration of its component storm drains, secondary streets, and primary streets (Fig. 6).[11]

Stormwater harvesting involves a two-step preparation (Han 2021; Sun 2014, pp.32–33). Before a storm event, the villagers sweep debris and dirt from the slated harvesting surfaces around the cistern inlets [see the underground cistern diagram (A) in Fig. 3] so that stormwater runoff will not carry them into the cisterns. The villagers also make sure that the cistern inlets are capped so that *the first flush*—the initial part of the stormwater runoff, usually the most polluted (Grant 2016, p.133; Mamun et al. 2020, p.2 of 10)—will not get in. During a storm event, the villagers uncap cistern inlets to capture and channel stormwater runoff to the cisterns after diverting the first flush to the storm drains in their own courtyards or to the roadside open channels along the streets (Fig. 6).[12]

2.3 Making cistern water potable

During and after a stormwater event, the villagers use both physical and chemical methods to make cistern water potable. They use the above-mentioned physical methods to catch and collect the highest quality stormwater possible when harvesting stormwater; they then apply self-made quicklime [calcium oxide (CaO)] powder to treat the cistern water—to purify, soften, and neutralize—making it potable (Han 2021). The use and making of quicklime powder are economical as there is plenty of limestone in the surrounding area and the production of quicklime from limestone is low tech and low cost.[13]

3 Two underlying ideas: ecophronetic and well-executed

The Yujiacun NDS has been safeguarding the village's water security for centuries. As a life support system, it lays a solid foundation for the survival and well-being of generations of villagers; its dual functionality operates effectively and incessantly when the natural pendulum swings between drought and flood. This enduring effectiveness reveals, and indeed results from, two ecologically wise (i.e., ecophronetic) ideas the villagers built the NDS upon.[14]

[11] All streets have moderate slopes, ranging from 10 to 15%, and are covered with stone pavers. This sloped permeability offers two advantages in regulating the movement of stormwater. It allows the stormwater runoff to flow without causing soil erosion and provides the time for the stormwater runoff to infiltrate when the soil underneath is unsaturated (NRCS 2021, p.2 of 2).

[12] For a review on the first flush phenomenon in urban stormwater management, see Mamun et al. (2020). For the practice of separating the first flush from stormwater runoff in ecological planning and design for water-sensitive cities and towns, see Grant (2016, p.133), among others.

[13] The use of quicklime powder in cistern water treatment is neither new nor unique. According to a 2011 national survey, there are approximately 4.5 million underground cisterns in the arid and semiarid rural areas in China; the use of quicklime in cistern water treatment is widespread (Lin 2011, p.3 of 8). It is not clear, however, when and from whom the Yujiacun villagers learnt to use this traditional chemical method.

[14] Both the adjective *ecophronetic* and the noun *ecophronesis* from which it derives were coined in 2016 by Chinese American geographer and planning scholar Wei-Ning Xiang (Austin 2018; Grose et al. 2019; Xiang 2016). Drawing upon the neo-Aristotelian conceptions of phronesis (i.e., practical wisdom), Wei-Ning Xiang regarded ecophronesis (i.e., ecological phronesis) as the practical wisdom that people acquire and use in their socio-ecological practice, and provided the following definition: "ecophronesis is the master skill par excellence of moral improvisation to make, and act well upon, right choices in any given circumstance of [socio-]ecological practice; motivated by human beings' enlightened self-interest, it is developed through reflective [socio-]ecological practice" (Xiang 2016, p.55; parentheses added by the authors of this article). Two years later, in 2018, British theological ethicist Nicholas Austin offered "a more fully ethical and theological account of ecophronesis" and advocated "an ecological adaptation" of ecophronesis as "a guiding ecological virtue" (Austin 2018, pp.1009–1010). He wrote, "For those who locate the roots of the ecological crisis in human cupidity, pride, and technoscientific domination of nature, the holistic practical wisdom of ecophronesis, put at the service of an integral human and ecological

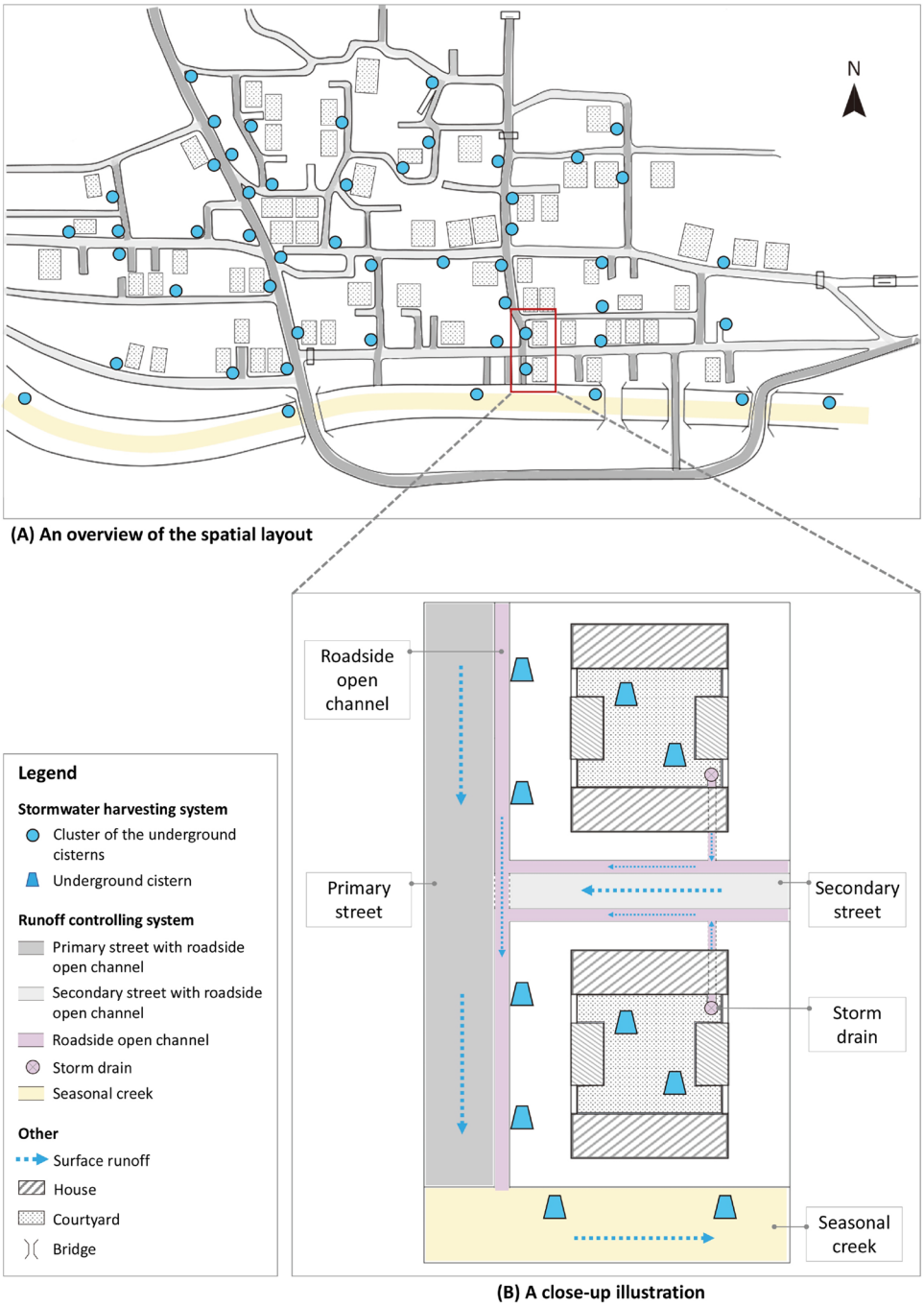

Fig. 5 Illustrations of the spatial layout of the Yujiacun NDS. [**Note**: a cluster of the underground cisterns (blue circle in **A**) may contain multiple underground cisterns (blue trapezoid in **B**); for illustration of the three types of underground cisterns, see Fig. 3] (colour figure online)

3.1 The ecophronetic idea of *working with the duality of stormwater*

To the Yujiacun villagers, stormwater is both an asset and a nuisance. As an asset, stormwater is the principal water source they can count on for life, livelihood, and prosperity (see subsection 1.1 of this article); as a nuisance, stormwater's destructive potential constitutes a very real common threat of flooding to all inhabitants of the village and to their properties.[15] Every storm event, therefore, is a double-edged

Footnote 14 (continued)

good, offers the prospect of an attractive corrective…. Ecophronesis, then, is the practical wisdom we need to live well in what Pope Francis refers to as 'our common home'" (*Ibid*., p.1009).

[15] A common threat is a danger—something or someone that can hurt or harm people—that may happen to every individual human being in a certain place (e.g., the Earth, a country, a region, a city, a village, or a community) to the extent that no one in that place is immune; a common threat can come from a natural disaster, a human conflict, or a combination of both (Palko and Xiang 2020, p.260; Xiang 2020a, p.200; Xiang 2021, p.239).

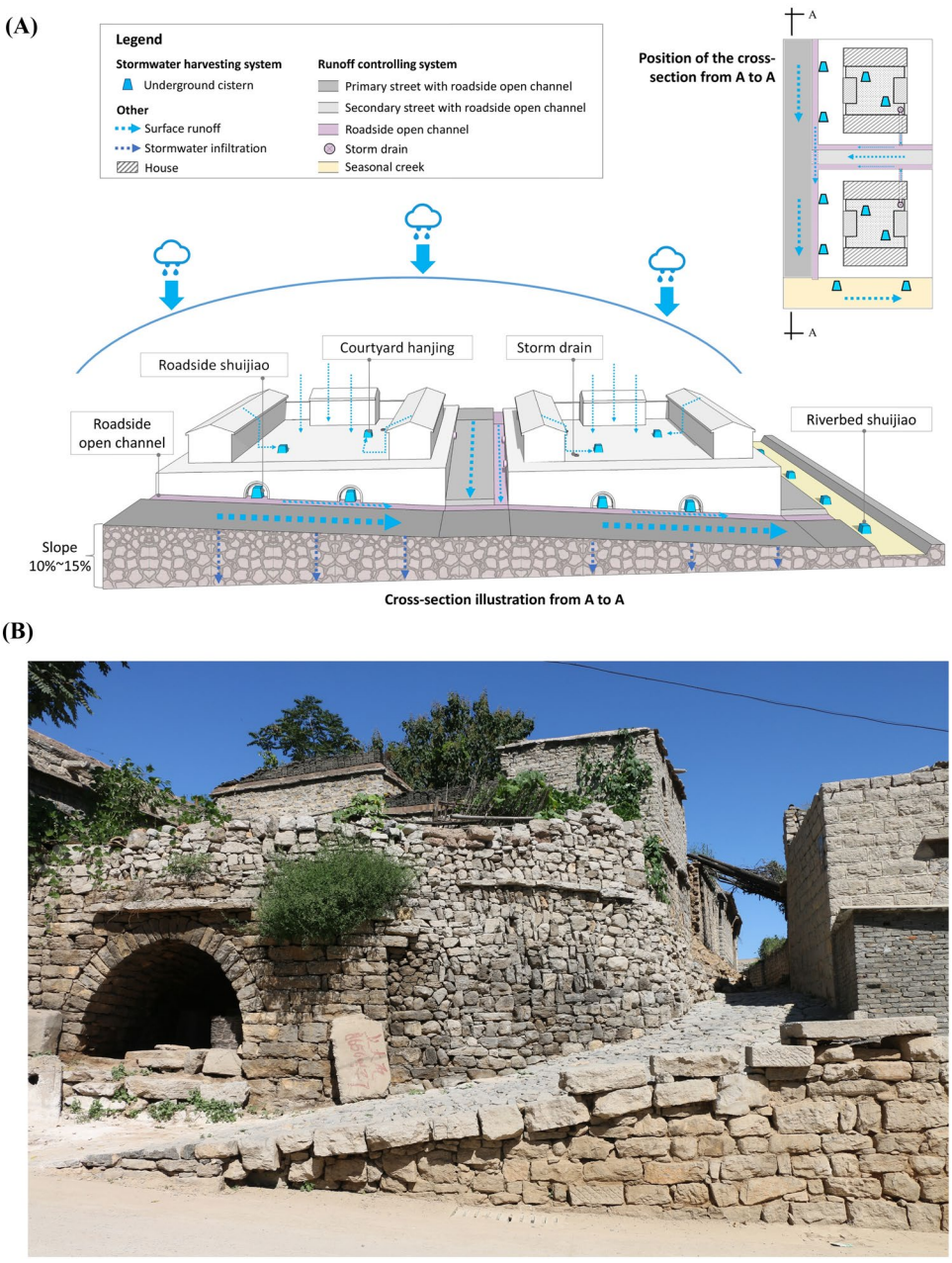

Fig. 6 (**A**) A cross section illustration of the Yujiacun NDS's dual function during a storm event. (**B**) A photograph taken at the intersection of a primary (from the left to right) and a secondary street by Han Chao on August 27, 2016; use with permission. [**Note**: for illustrations of the three types of underground cisterns, see Fig. 3]

sword. On the one hand, it presents the villagers a critical window of opportunity for stormwater harvesting to secure their water supply; on the other hand, it puts huge pressure on the villagers to divert stormwater as quickly as possible to the outside of the village to reduce flood risk.

For the villagers, therefore, working with the duality of stormwater is a must. By "working with", it means to reach two goals simultaneously during a storm event: taking advantage of the constructive side of stormwater; avoiding or mitigating the destructive side. This time-sensitive, high-stakes, and recurring task entails a delicate exercise of coordinating two opposite water security processes: keeping some portion of stormwater in the village for subsequent use and letting the rest go outside the village to prevent flood.

The phenomenal working of the bifunctional NDS, as we presented in the previous section, is both a manifestation of this idea and a testimony of its powerful efficacy: the drainage system this ecophronetic idea led to has been ably managing the duality of stormwater with an effective and robust dual functionality for centuries.

It is noteworthy that the idea *working with the duality of stormwater* has its root in the Chinese cultural belief in *duality of nature*. In a 2009 essay for *Encyclopedia of positive psychology*, the Chinese-Canadian psychologist Paul PT Wong posits that the belief in duality of nature and five

other cultural beliefs and a concomitant set of signature virtues have enabled the Chinese people to survive the myriad vicissitudes of life for more than 5000 years (Wong 2009, p.152, p.155).[16] Specifically, the belief in duality of nature (1) recognizes the coexistence of opposites (e.g., good and bad) in both nature and human nature as a universal truth; (2) regards the balance between the opposites, however uneasy it is, as the best way toward a good life and better world; (3) values the individual and collective efforts to embrace the opposites in work and life and to maintain a dynamic balance (*Ibid*., p.153). This strong cultural root helps explain the fact that, throughout China's 5000-year history, the idea of working with the duality of stormwater has been widely and effectively executed in many areas in China [e.g., the Fushougou (福寿沟) stormwater management system in Ganzhou (赣州), China (1069–present) (Han 2012; La Rosa et al. 2021, p.331)]. Equally noteworthy is the revival of the very idea in the twenty-first century—it has been gaining significant popularity in urban areas in China and around the world and underlies such contemporary movements as "water sensitive city" (Grant 2016), "water sensitive urban design" (Wong et al. 2013, p.11), "modern stormwater management" (Holm et al. 2014, p.2 of 4), and "sponge cities" (Zevenbergen et al. 2018, pp.3–4 of 13).

3.2 The ecophronetic idea of *building with nature*

To the Yujiacun villagers, a bifunctional drainage system is ideally *double high* and *triple low*. "Double high" refers to the high effectiveness and high robustness of the system—its built-in dual functionality operates properly and incessantly when the natural pendulum swings between drought and flood; "triple low" means that the system is technologically simple (low-tech); requiring little money, time, or effort to look after (low maintenance); and causing minimum harm to the already fragile environs (low impact). A double-high and triple-low bifunctional drainage system is ideal because it meets the villagers' water-security needs in a technically feasible, resource-efficient, and affordable fashion (Zhao et al. 2018, pp.41–42, p.44). For the villagers, therefore, building such a system is the right thing to do without doubt.

But then, what would be the right way to do this right thing? In other words, how should a bifunctional drainage system be built that meets the double-high and triple-low criteria? The villagers' answer was, building with nature, that is, in the design and construction of the drainage system, harnessing the properties, functions, and processes of in situ natural ecosystems as well as using locally available natural materials.

Manifesting this idea, as we presented in Sect. 2, the Yujiacun NDS is built entirely with nature. The sloped permeable streets use moderate inclines and stone pavers to regulate the speed of surface runoff and allow stormwater infiltration; the three-leveled stormwater conveyance network mimics a natural drainage system to divert stormwater by virtue of gravity; the 1000-plus underground cisterns utilize underground space and take advantage of the relatively constant temperature of the Earth to store and supply water year-round; the cisterns are built with stones from the surrounding mountains; the cistern water is treated with quicklime powder whose production from limestone is both economical and low tech. These and other built-with-nature features together make the Yujiacun NDS an extraordinary feat of socio-ecological practice that has been ably safeguarding water security in a double-high and triple-low fashion for its conscientious builders and their posterity for centuries.[17]

It is noteworthy that the idea of *building with nature*, like that of *working with the duality of stormwater*, is neither new nor unique. It in fact has a close affinity with *design with nature*, another perpetual idea which was reemerged in the 1960s in the USA and made prominent by Scottish American landscape planner and educator Ian McHarg through his 1969 book "Design with nature" (McHarg 1969; Lyle 1999, p.45). These two comparable ideas share a common aim to "give expression to the potential harmony of man-nature" (McHarg, 1969, p. 5) and have been found underlying a great many extraordinary feats of socio-ecological practice that provide lasting benefits and stand the test of time. These exemplary engineering feats include, but are definitely not limited to, the Dujiangyan (都江堰) irrigation system in Sichuan, China (256 BC–present) (Needham et al. 1971, p.288; Xiang 2014, pp.65–66); the aforementioned Fushougou (福寿沟) stormwater management system in Ganzhou (赣州), China (1069–present) (Han 2012; La Rosa et al. 2021, p.331); the Red Flag Canal in Henan, China (1969–present) (Chen and Xiang 2020a; b; Li et al. 2021; Xiang 2020b); the Woodlands New Community in Texas,

[16] **[1]** Cultural beliefs are conceptions about the world and human life a group of people hold as true, important, and desirable for good life (Edwards and Jarrett 2009, p.265; Greif 1994, p.915; Wong 2009, p.152). Cultural beliefs influence how people think, what they value, and how they behave and cope (Fan 2000, p.4; Greif 1994, p.915; Wong 2009, p.148). **[2]** For a succinct account of the six cultural beliefs and virtues Wong presented, see Palko and Xiang (2020, p.262).

[17] "Socio-ecological practice is the human action and social process that take place in specific socio-ecological context to bring about a secure, harmonious, and sustainable socio-ecological condition serving human beings' need for survival, development, and flourishing. It is the most fundamental and arguably primordial social practice Homo sapiens has been involuntarily engaging in over thousands of years of co-evolution with nature. Socio-ecological practice includes six distinct yet intertwining classes of human action and social process—planning, design, construction, restoration, conservation, and management" (Xiang 2019a, p.7).

Table 1 Characteristics of an effective NBS project. [adapted from La Rosa et al. (2021, p.330)]

	Characteristics of an effective NBS project
1	The project is inspired and supported by nature and harnesses the properties and functions of natural ecosystems
2	Its GI products provide ecological, social, cultural, and economic benefits
3	The project, through its GI products, brings more natural features and processes into cities and communities;
4	Its GI products are locally attuned, resource efficient, multi-purpose, and multi-functional
5	The project and its GI products stand the test of time

USA (1974–present) (Forman 2002, pp.102–104; Lyle 1999, p.103, p.237; McHarg 1996, pp.256–264; Xiang 2016, pp.56–57; Xiang 2019b, pp.166–167; Yang 2019; Yang and Li 2016, 2019, pp.217–219); afforested woodlands in the Alps (Knott 1991; Mayer and Ott 1991); Škocjanski Zatok Nature Reserve in Koper, Slovenia (Ivajnšič and Kaligarič, 2014; Jurinčič et al. 2011); ancient woodlands and urban parks in many European cities, such as Eilenriede in the heart of Hanover, Germany (Hannover 2016; Oppermann and Thies 2017), and the hitherto best-kept secret—the Yujiacun NDS.

However, unlike most on the above honor roll, little is known about the centuries-long process of building with nature that led to the Yujiacun NDS because much of it is undocumented. Questions that arise and await answers include, *inter alia*: How and when did the villagers come up with the idea of building with nature? What were some specific challenges they encountered throughout the process of building with nature? What exactly did they do to overcome the challenges? How did they figure out both the right thing to do in the face of these challenges and the right way to do the right thing? Did they choose to pursue the triple-low simply by default because no modern sciences, high technology, high building materials (for example, cement, steel), and funding were available to them? Until this knowledge gap is filled, or at least narrowed substantially, the Yujiacun NDS, as the tangible product of the building-with-nature process, is the researchers' best friend.

4 A strong candidate for the international depository of time-honored NBS examples

In "Unearthing time-honored examples of nature-based solutions", a 2021 guest editorial published in this journal by three international planning scholars, authors Daniele La Rosa (Italy), Stephan Pauleit (Germany), and Wei-Ning Xiang (the USA) advocate the unearthing and documenting of time-honored NBS examples and propose the establishment of an international depository of these examples (La Rosa et al. 2021, pp.332–333).

They define NBS, the initialism for nature-based solutions, as "human actions and social processes through which people from all walks of life work together to build and/or renovate nature-inspired, ecosystem-based green infrastructures (GIs) that help address the environmental, social, and economic challenges they face and meet their needs for survival, development, and flourishing" (La Rosa et al. 2021, p.329). They propose that time-honored NBS examples are the NBS projects that meet two basic criteria: They are effective and possess five key characteristics (Table 1); they are real-world problem-solving projects, in lieu of demonstration projects, created inadvertently by generations of practitioners through a trial-and-error process of bricolage and tinkering (*Ibid.*, p.332).

Then, the question is, by these standards, would the Yujiacun NDS as we know it be qualified to be *a time-honored NBS example* and could therefore be inducted into "The international depository of time-honored NBS examples" (La Rosa et al. 2021, p.333)?

At the present time, we are somewhat ambivalent. On the one hand, it is hard not to say *yes*, even with the arguably moderate amount of information (still the best available) presented in this showcase article. The Yujiacun NDS clearly meets both criteria above-mentioned: It is an extraordinary and beneficial feat of socio-ecological practice that results from a centuries-long project of real-world problem-solving, and the project possesses all the five key features of an effective NBS project listed in Table 1. But on the other hand, it is difficult to say *yes* with full confidence, because many knowledge gaps remain to be filled. These include those about, *inter alia*, the centuries-long process of building with nature (as is mentioned in subsection 3.2), the governance of the NDS, the roles of cultural beliefs and guanxi practice in the NDS construction and governance.[18] Nonetheless, we have every confidence that the Yujiacun NDS is for sure a strong candidate and, as more knowledge gaps are filled or

[18] The Chinese noun guanxi (i.e., 关系) generally means a relationship between objects, processes, or people; and here it refers to an interpersonal relationship or a web of social relationships. Guanxi practice is the reciprocal act and process of cultivating, sustaining, and employing guanxi toward mutually beneficial ends (Li et al. 2021, p.389).

narrowed, will gain the formal recognition and admittance. We will continue our pursuit toward that end.

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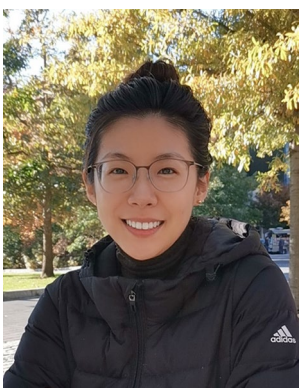

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