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Entangled materials: rice husk, straw, and circular practices in multispecies networks

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Abstract: This paper investigates the emerging possibilities of rice husk and straw as building materials within evolving ecological material practices in architecture, grounded in ethnographic research in Qingpu, Shanghai. Although often treated as residues with limited or low-value uses, their exclusion from construction reveals deeper socio-technical and ecological entanglements. Drawing on Actor-Network Theory (ANT), the study maps the political, infrastructural, and multispecies networks that shape material reuse, highlighting the frictions that influence their trajectories. Set in Qingpu—a historically agricultural landscape bordering Dianshan Lake, Shanghai's largest freshwater body—the research adopts a transcalar perspective to trace processes from microbial activity in soils to regional infrastructures and policy frameworks. Fieldwork consisted of seven semi-structured interviews with the operator of a government-recognized family farm, ten informal interviews with cooperative farmers, and 24 site visits across two planting and harvesting cycles (2023–2025), combining participant observation with interview-based insights. This revealed interconnected actors: infrastructures, ecological relations, regulatory frameworks, and multispecies assemblages that define material possibilities. Rather than treating current limitations as fixed barriers, the study emphasizes the potential of these entangled networks to reconfigure alliances between human and more-than-human participants. It shows how infrastructures, ecological systems, regulations, and cultural perceptions of cultivated materials intersect to open pathways for circular practices. ANT provides a lens to trace negotiations across human and nonhuman actors. By grounding material reuse in multispecies entanglement, the study contributes to discourses on ecological repair, context-specific technologies, and architectures of circular practice, and advocates repositioning rice husk and straw as active participants in socio-ecological networks—where circularity is not merely technical but a situated practice of care.

Keywords: Rice husk and straw; actor-network theory (ANT); multispecies design; ecological architecture.

1. Introduction

The concept of circularity—designing material and resource flows to minimize waste and maximize reuse within closed-loop systems—has become central to sustainability discourse and architectural practice (Kirchherr, Reike, & Hekkert, 2017; Pomponi & Moncaster, 2017). Yet in practice, circularity is often reduced to technical strategies such as industrial-scale recycling, overlooking more transformative or situated approaches to material use (Allwood, 2014). This tendency becomes especially limiting in agrarian and peri-urban contexts, where materials like rice husk and straw are embedded in complex human and more-than-human negotiations that resist standardization.

This paper examines why rice husk and straw—plant materials left behind after harvest—are rarely reused in architecture in Qingpu, a peri-urban district on the edge of Shanghai. Although these materials have shown potential as sustainable components in construction, such reuse remains marginal in China, where straw is primarily directed toward fertilizer, feed, and fuel applications (Sun et al., 2022). The study focuses on a rice cooperative in Xueji Village, Jinze Town, which is part of a government-supported zone for ecological rice cultivation and farmland modernization. The site's emphasis on ecological intensification and state-backed infrastructural upgrades offers a critical vantage point for examining how circularity plays out in practice.

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Between 2023 and 2025, I conducted fieldwork following the seasonal cycles of rice farming, tracing how husk and straw emerge, move, and transform through seasonal farming practices and local infrastructures. This approach shows that waste is not a neutral category but one shaped through interactions among water, infrastructure, microbes, policies, and labor routines.

The research combines ethnographic methods with Actor-Network Theory—drawing on foundational contributions (Latour, 2005; Callon, 1986; Law, 1992)—to map the socio-material assemblages that define what waste is and what it might become. Rather than treating spatial levels as discrete, the analysis adopts a transcalar perspective that emphasizes how spatial and governance scales are overlapping, interrelated, and mutually constitutive. This perspective foregrounds how microbial, infrastructural, and policy domains are entangled and co-productive. Instead of proposing design solutions, the paper reflects on how exclusions are configured, offering a situated understanding of circularity in architectural discourse.

2. Methodology

2.1. Research design and fieldwork approach

This research draws on an ethnographic and material tracing approach to investigate how rice husk and straw are produced, managed, and excluded from reuse within Qingpu's agricultural and infrastructural systems. Fieldwork was conducted over repeated visits between 2023 and 2025 in the rice paddies of Xueji Village, Jinze Town, a peri-urban area on the western edge of Shanghai.

The study site is operated by the Shanghai Xuhui Agricultural Cooperative and forms part of a government-supported zone for ecological rice cultivation and farmland modernization. These programs promote practices such as intermittent irrigation, ecological planting zones, and the use of light traps to manage insect populations, alongside state-funded investments in irrigation and drainage infrastructure. The site represents a model of ecological intensification shaped by a combination of policy goals, local labor, and mechanized production.

The research focused on rice cultivation practices and residue management within and around the cooperative-managed area, including one government-recognized family farm operating on leased plots. Farming practices in the region typically involve both hybrid and inbred rice varieties, including Huayou 14 (hybrid) and Nanjing 46 (inbred), and rely on mechanization and targeted use of agrochemicals. Herbicides are purchased and applied by farmers to manage weeds along field ridges and within paddies. Insecticides, by contrast, are distributed free of charge by the local Agricultural Technology Center, based on field observations of insect activity. These typically include pymetrozine, milbemectin, and tricyclazole, promoted as lower-toxicity alternatives under current agricultural programs—though their environmental impact remains context-dependent, particularly in relation to water systems and long-term soil health.

Data collection combined interviews, participant observation, and visual documentation:

- Semi-structured interviews: Seven in-depth interviews with the operator of a government-recognized family farm, following a semi-structured format. The framework drew on Actor–Network Theory (Latour, 2005; Callon, 1986; Law, 1992) and multispecies approaches, with themes on farming practices, residue handling, and reuse potential.
- Informal interviews: Ten additional interviews conducted on six occasions with cooperative farmers, providing further perspectives on cultivation and residue management.
- Participant observation: 24 site visits over two planting and harvesting cycles (2023–2025), enabling documentation of seasonal rhythms and everyday practices.
- Field observations: Direct observation of planting, harvesting, drying, threshing, and residue handling.
- Visual methods: Photographic documentation and paddling exploration of canals to trace links between fields, water infrastructures, and settlement edges.
- Remote sensing: Visual analysis of satellite imagery to identify spatial patterns and land-use changes.

All interviews were conducted in Chinese with the assistance of a research assistant acting as a translator.

This mixed-method approach enabled the tracing of material flows and socio-ecological dynamics—from soil preparation and mechanization to residue accumulation and disposal—foregrounding the multiple agents involved in shaping what is categorized as waste and under what conditions.

The research combines ethnographic methods with Actor-Network Theory (ANT)—drawing on foundational contributions from Latour (2005), Callon (1986), and Law (1992)—to map the socio-material assemblages that define what rice husk and straw are and what they might become. ANT enables a relational reading of these

materials, treating farmers, residues, microbes, infrastructures, and policies as active participants in shaping value, exclusion, and reuse.

Rather than treating spatial and governance levels as discrete, the analysis adopts a transcalar approach that emphasizes how spatial and institutional scales are overlapping, interrelated, and mutually constitutive. This perspective foregrounds the entanglement of microbial processes in saturated soils with regional water governance, infrastructural upgrades, and national agricultural policy, offering a more situated understanding of circularity beyond technical reuse models.

Ethnographic data—including interviews, field notes, and visual documentation—were interpreted relationally and thematically, tracing how interactions among human and nonhuman actors shape the conditions under which rice residues are classified and managed. Instead of isolating variables or proposing design solutions, the analysis emphasized assemblages and situated contingencies.

Throughout the research process, attention was paid to ethics and positionality. Verbal informed consent was obtained prior to interviews and photography, and identities were anonymized. As a researcher based in an urban university, I remained attentive to the power dynamics of knowledge production and engaged participants in reciprocal dialogue, sharing early findings informally during return visits.

3. Results

3.1. Water: Cycles, Infrastructures, and Interdependence

In Qingpu, the rhythms of rice cultivation are intricately shaped by the movement of water. Every stage—from transplanting to harvest—depends on an irrigation system almost entirely supplied by Dianshan Lake (Figure 1), Shanghai's largest freshwater lake, located in the Yangtze River Delta (YRD). Covering 62 square kilometers, the lake is a vital reservoir, not only for agriculture but for also municipal drinking water. Its shallow depth and vast surface area make it particularly sensitive to ecological changes. Water is pumped from its tributaries into the fields through a network of government-built irrigation stations, maintained by village committees. Farmers adjust the flow and timing of water according to seasonal and planting cycles, managing both agricultural needs and ecological impacts.

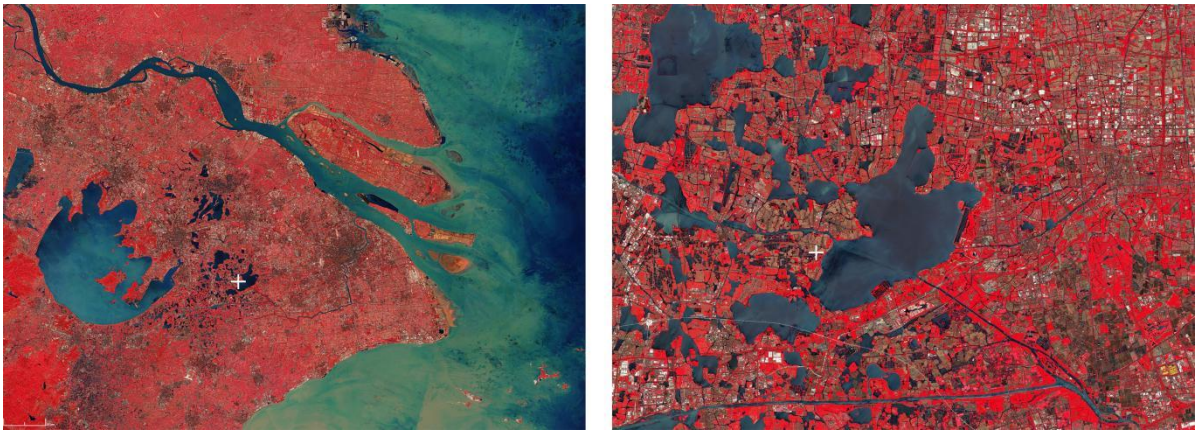

Figure 1: Sentinel-2 L2A false color image YRD and Dianshan Lake, 2025. (source: Copernicus, 2025)

Dianshan Lake spans administrative boundaries—part in Shanghai, part in Jiangsu Province. Water circulates freely across jurisdictions, indifferent to borders yet influenced by the policies that govern them. Its condition depends not only on local land use but also on upstream decisions and cross-regional governance. According to Qingpu District's 14th Five-Year Plan for Water System Development (2021–2025), current initiatives include controlling agricultural non-point source pollution—diffuse nutrient and chemical runoff from fields—as well as shoreline protection, smart water monitoring systems, and ecological buffer zones (Qingpu District Government, 2021).

On the ground, farmers report visible improvements in lake health, attributing these changes to the ban on electrofishing, relocation of polluting factories, stricter livestock regulations, and regular garbage collection by

boat. Tributaries once degraded have been partially restored, and the lake is now treated not just as a water source but as a vital ecological system that requires active care.

However, despite these improvements, the interaction between water, agriculture, and ecosystem health remains complex. A 2021 study based on monthly monitoring at five sites in Dianshan Lake found that although oxidizability (CODMn) had improved to meet Class III water standards—considered suitable for drinking after treatment—levels of total nitrogen and phosphorus still exceeded thresholds linked to eutrophication (Yu et al., 2025).

Field observations underscore the role of fertilizer use in this ongoing process. A slow-release compound fertilizer commonly applied in the study area contains 30% nitrogen and 6% phosphorus (P_2O_5). Despite its slow-release formulation, the large-scale application via motorized spreaders contributes to nutrient runoff, particularly during the rainy summer season. These nutrients accumulate in adjacent aquatic systems, creating conditions for cyanobacterial blooms, such as Microcystis, which reduce oxygen levels, disrupt food webs, and release toxins into the water and local biota.

Drone-based spraying of fertilizers and insecticides further complicates this dynamic. Although these inputs are promoted as efficient and lower in toxicity, they operate within a porous irrigation system where chemical residues and microbial communities circulate between fields, canals, and the lake. Water is not only an agricultural input but also a vector of lifeforms—linking the processes of agricultural fields with the broader hydrological and ecological system that ultimately extends to the East China Sea.

In Qingpu, water is more than a technical medium. It is governed, inhabited, and alive. It sustains more than just crops: aquatic plants, fish, snails, frogs, insects, and microbes all move through its flow. In flooded fields and drainage canals, water becomes a shared ecology, connecting field and lake, human practice and ecological process, microbial metabolism and agricultural intervention. Water flows between infrastructure and ecology—always circulating, never still.

3.2. Soil: Standardization, Microbial Life, and the Unfinished Project of Monoculture

Qingpu's rice-growing areas follow a recurrent seasonal cycle: single-season rice, planted and harvested once per year, followed by winter cover crops like broad beans or clover. Since 2012, late-season rice has been phased out, with local authorities encouraging practices aimed at maintaining long-term soil fertility. These cover crops are returned to the soil in spring as green manure, replenishing essential nutrients—a method confirmed by both policy documents and farmers during fieldwork.

In Qingpu's fields, soil is not merely something we walk on. It clings to boots, gets under fingernails, and carries a particular smell after rain. While it may seem like a uniform surface at first glance, soil is a complex, living system. Below the visible surface lies a world of microorganisms, fungal strands, and insect tunnels, all sustaining the crop above. This hidden ecology is fundamental to rice cultivation, influencing the growth and resilience of crops. Soil holds the memory of past plantings and nutrients from decomposed residue, shaping each planting season and directly impacting farming practices.

The land preparation process is highly mechanized, involving both human labor and specific technologies. First, slow-release fertilizer is spread, followed by tilling, flooding, leveling, and puddling to create a uniform, muddy surface. In the next stage, plastic trays of young rice seedlings are moved from the nursery to a small truck using a portable rail-based seedling conveyor system. Farmers then move the conveyor itself, which is disassembled and transported in parts, to new locations in the field. Once the trays reach their final destination, they are placed into the riding-type transplanter (Figure 2). One person operates the transplanter, while another controls the trays to ensure the seedlings are positioned correctly. Despite the reliance on mechanization, human labor remains essential, with farmers adapting to the irregularities of the land and the specific needs of the soil at each stage.

Figure 2: Nursery and conveyor system (source: photo by the author, 2025)

The planting grid in the fields is never perfectly straight. It follows imperfect lines shaped by the landscape's natural features and the path of the machines, driven by the farmers. These paths are neither smooth nor perfectly straight, reflecting the constant adjustments made to navigate the land's characteristics. The presence of physical obstacles, such as electric posts and trees, disrupts the idealized system, exposing the limitations of mechanization and illustrating that farming is a continuous negotiation with the environment. As Anna Tsing (2015) highlights, real-world frictions—whether from terrain, infrastructure, or unforeseen events—undermine the illusion of control, showing that farming systems are inherently adaptive, partial, and unpredictable.

Soil preparation compresses the surface ecology, limiting variability in plant growth and microbial distribution. Yet even this controlled process is interrupted by the land's irregularities and the unpredictable dynamics of farming. These disruptions reveal that monoculture is not a fully standardized system, but a continuous, adaptive process shaped by the forces it must accommodate.

Along the borders of the rice fields, both improvised and institutional interventions accumulate. Discarded fireworks tubes and plastic containers appear alongside solar-powered UV insecticidal lamps, installed by local authorities to attract and electrocute insects at night using ultraviolet light. These devices form part of the rice field management strategy, aimed at reducing chemical inputs. Together, they mark the field's edge as a zone where rural governance, technological improvisation, and ecological management intersect—not only above ground, but in ways that materially shape the soil and its life forms. The rice crop progresses through several growth stages, each dependent on the soil's ability to support the plant with water, nutrients, and an appropriate microbial environment. Nitrogen-fixing bacteria and methane-producing archaea mediate relationships between rice roots, fertilizers, and water. These microbial communities are integral to the soil's health, influencing the productivity of the rice fields. Despite mechanized preparation, soil remains an active agent, continuously shaping the agricultural system and requiring ongoing negotiation between human needs and ecological processes (Figure 3).

Figure 3: Rice planting frictions (source: photo by the author, 2025)

Soil is not only an active agent in shaping the routines of farmers but also impacts the broader ecology of the area. By regulating the presence and possibilities of life forms, such as insects, birds, and amphibians, soil directly influences the biodiversity of the rice fields, supporting a multispecies environment. The health of the soil also has profound effects on water quality in Dianshan Lake, which serves as the water source for four million people. The runoff from the rice fields can carry nutrients, chemicals, and organic matter that influence the health of the lake's ecosystem, as well as its capacity to sustain local communities.

Beyond the immediate agricultural system, the soil's relationship with water and microbial life also plays a role in climate dynamics. Rice farming, particularly in flooded fields, creates anaerobic conditions that lead to the production of methane, a potent greenhouse gas. The rice fields of Qingpu thus contribute to the atmospheric levels of CO2 and methane, with direct implications for climate change. While mechanized practices aim to control this process, the underlying ecological interactions that take place beneath the soil surface continuously influence the broader environmental system.

Despite the mechanized preparation, the rice field remains a dynamic, multispecies environment. While the fields may appear seemingly quiet at first glance, closer observation reveals the presence of life forms—such as insects, birds, and amphibians—that introduce diversity and unpredictability. These organisms, along with the soil itself, disrupt the ideal of monoculture, transforming the rice field into a dynamic, adaptive environment shaped by both human and nonhuman forces.

In Qingpu, soil is not just a passive medium for rice cultivation. It is an active agent, shaping the farming process and influencing both the routines of farmers and the broader ecological systems, from biodiversity to water quality and climate dynamics. The constant negotiation between mechanization and ecological dynamics makes the soil a site of both friction and adaptation. This dynamic relationship enables the system to remain resilient, adapting to both human needs and ecological challenges (Figure 4).

Figure 4: Rice transplanter in Qingpu (source: photo by the author, 2025)

3.3. Species: Encounters and shared territories

Rice farming in Qingpu unfolds within a more-than-human landscape. Fields, canals, and aquaculture ponds form part of a dynamic multispecies environment where birds, insects, amphibians, mammals, and mollusks intersect with human activity. Some of these presences are welcome or incidental; others become subjects of management, deterrence, or harm. The result is a shifting terrain of coexistence, friction, and ecological improvisation.

During fieldwork, several encounters revealed the porous and often fragile boundaries between agricultural infrastructure and nonhuman life. A white heron was found tangled in a wire strung above a shrimp pond—a

deterrent intended to protect aquaculture stock. With the help of a nearby farmer, we untangled the bird and watched it fly, unsteadily, toward the canal. On another day, a hedgehog was discovered trapped inside a cylindrical fishing net, likely swept in from nearby ponds. A stray cat wandered along the canal bank with a plastic cup stuck over its face, disoriented and struggling to remove it. These were not isolated events. They underscored how tools and infrastructures—whether designed to deter, contain, or serve unrelated functions—can take on unintended agencies through their material entanglements, becoming hazards for other species.

Qingpu lies along the East Asian–Australasian Flyway, a major bird migration corridor. Migratory species such as herons and egrets use the rice paddies, drainage channels, and aquaculture zones as seasonal stopovers. Even the most utilitarian infrastructures—tractor paths, bunds, irrigation ditches—become embedded in broader ecological corridors. In early summer, birds trail behind tractors as they churn the soil, opportunistically feeding on worms and insects exposed by the blades. These moments reflect more than passive coexistence; they reveal a kind of ecological opportunism, where one species' disturbance becomes another's niche.

Yet not all species integrate so fluidly. The apple snail (Pomacea canaliculata) has become a major concern among farmers. Introduced in the 1980s from South America via Taiwan as a food source, the snail now flourishes across Qingpu's aquatic systems—from flooded rice paddies to roadside ditches. During fieldwork, clusters of its bright pink eggs were observed clinging to canal walls just above the waterline, as well as on the rice plants themselves. Farmers described how these snails feed on newly transplanted rice shoots, sometimes destroying entire fields within days. In response, pesticides are applied multiple times per season, with mixed results. Some recalled earlier methods of integrated farming—raising ducks to control snails and weeds while fertilizing the soil—but this practice has been banned for sanitation reasons.

Unlike birds or hedgehogs, the apple snail is not merely incidental. Its presence restructures farming calendars, labor routines, and chemical inputs. It crosses boundaries between agriculture and aquaculture, between canal and field, occupying marginal zones that elude precise management. What makes it disruptive is not only its biology, but its spatial behavior—thriving at the edges of human control, in ecotones and infrastructural gaps.

In the study of rice fields in Thailand, Heckman (1979) recorded the astonishing biodiversity of tropical rainfed paddies, noting that a single rice field could support up to 589 species. This level of biodiversity—though much higher than in the mechanized fields of Qingpu—highlights the principle that rice farming can coexist with a rich variety of species. Like the fields of Qingpu, the Thai rice paddies challenge the notion of monoculture, revealing how agriculture and biodiversity can co-evolve, complicating the simplification of farming practices.

These interspecies interactions complicate the notion of the rice field as a tightly managed monoculture. They expose a material and ecological porosity, where species mobility, microbial life, and land management are in constant negotiation. In Qingpu, farming is not solely a human act of cultivation—it is an ongoing choreography within a crowded, contested, and entangled field of life.

3.4 Rice Harvesting, Straw, and Husk — Practices and Possibilities

Harvesting in Qingpu is a tightly coordinated process, organized by the cooperative to synchronize machinery, labor, and storage capacity. Most farmers now cultivate single-season rice with a growing period of approximately six months—from late May or June to harvest in November. Farmers recalled that earlier cycles lasting only three to four months produced rice considered less palatable, prompting the shift toward longer cultivation periods. One younger farmer interviewed managed approximately 20 mu (1.3 hectares), planting both hybrid (Huayou 14) and inbred (Nanjing 48) rice varieties. These choices were made through cooperative guidance and supported by local agricultural subsidies, reflecting how varietal selection is shaped by institutional as well as agronomic considerations.

Rice is harvested mechanically, using mechanical combine harvesters that cut the plants, separate the grains, and leave the straw behind in a single pass. In many cases, the machine returns only for a second sweep to collect the loose straw into piles, which are then mulched or plowed back into the soil. This process reduces labor and complies with official policies discouraging straw burning, once a common practice. Yet it also precludes the possibility of carefully separating or preserving the straw for higher-value reuse. Even when straw is collected, it is typically stored informally along field edges or in temporary shelters, with no clear infrastructure for organized reuse.

The husk, separated during milling, presents different challenges. It accumulates in cooperative warehouses or local processing centers, sometimes in significant quantities. Limited reuse occurs—for example, as animal bedding or low-grade filler—but applications such as insulation or biofuel remain rare. Farmers lack both the

market networks and technical infrastructure to process husk into construction-grade materials. As a result, husk remains abundant yet underutilized within human production systems, despite its ecological value in soil enrichment (Figure 5).

Figure 5: Rice fields in harvest time (source: photo by the author, 2024)

This relative invisibility is not accidental. The conditions that produce straw and husk as waste—mechanical harvesting, standardized seed varieties, government yield targets, ecological policy constraints—also limit how that waste can be reimagined. Construction materials demand regularity, cleanliness, and supply-chain stability. Rice residues emerge from systems that are messy, seasonal, and spatially dispersed. Farmers focus on yield, timing, pest control, and compliance—not on the material afterlives of their by-products. When reuse does occur, it is improvised: composting, mulching, or low-cost bedding. These practices are ecologically sound but economically peripheral.

More than a technical gap, this points to a conceptual and infrastructural disconnect. Waste here is not simply leftover—it is materially shaped by the very infrastructures and policies that define production. The machines that compress the soil, the schedules that coordinate harvests, the policies that restrict burning, and the absence of localized reuse networks all work together to frame straw and husk as excess, rather than material participants in wider socio-ecological assemblages.

As such, the challenge of reuse is not only material, but spatial and political. For rice residues to enter circular design systems—as insulation panels, composites, or low-carbon construction inputs—they must first be recognized as material participants in an active and entangled field, rather than treated as passive surplus awaiting redirection. Their potential lies not only in chemistry or volume, but in reconfiguring how agricultural and architectural systems intersect (Figure 6).

Figure 6: Rice plant and rice grain drying (source: photo by the author, 2024)

4. Discussion:

4.1. From residue to relation - Reconfiguring straw and husk

Throughout this study, we have traced the seasonal, infrastructural, and ecological processes that generate rice husk and straw in Qingpu's fields. From canal networks and fertilizer runoff to the frictions of mechanized planting and the partial realities of monoculture, our results describe a web of interactions in which residues emerge not merely as waste, but as material participants within multispecies and socio-technical systems.

Rather than framing husk and straw as passive by-products awaiting human reuse, we propose viewing them as organic infrastructures—materials that shape microclimates, attract decomposers, enable microbial life, and sustain ecological relations. Their slow decay in fields supports nutrient cycles critical for future plant growth while providing food and shelter for insects, amphibians, birds, and soil organisms. In this sense, residues are not external to life but deeply interwoven with it.

This perspective complicates conventional narratives of efficiency and valorization. While husk and straw are materially abundant, they remain largely absent from dominant discourses on rice production. Farmers rarely mention them unless explicitly prompted, typically framing straw as a logistical burden. This friction within productive logics helps explain why residues remain invisible in policy frameworks and design agendas. Yet this discursive absence contrasts with their material vitality in everyday life: decomposing straw provides warmth and habitat, while husk creates microtopographies that host microbial agents and influence soil conditions. Their agency is not symbolic but material, shaping multispecies ecologies even when disregarded by regulation or omitted from architectural considerations.

These observations suggest that discussions of reuse should not begin with economic revalorization alone. More fundamental is the question: what relations are already sustained by these materials? What forms of care, decay, and cohabitation do they enable? Such questions reposition design from extracting value from residues toward participating in the ecological processes they already anchor.

Our findings on water infrastructure, soil life, multispecies interactions, and harvesting routines underscore that every technical intervention is also ecological, every residue a relational entity. The potential use of rice husk and straw as low-carbon construction inputs cannot be separated from the living systems they currently sustain. We therefore advocate for architectural thinking that recognizes materials as already situated and lively, foregrounding the ethical and ecological consequences of extraction, even when pursued under regenerative or circular ambitions.

4.2. Limitations and future research

This study highlights how rice husk and straw are framed as waste through infrastructural, policy, and cooperative arrangements in Qingpu, yet also demonstrates their potential as material participants in socio-ecological assemblages. While grounded in close ethnographic observation, the analysis is limited to one district and two cultivation cycles. Broader comparisons across different rice-growing regions would help to identify both shared patterns and local divergences in how residues are produced, managed, and potentially reused.

Another limitation lies in the scope of material experimentation. This paper focused on farming practices and infrastructures rather than laboratory testing. Further research is needed into the material possibilities of rice residues—their thermal, mechanical, and hydric performance as building materials—so that ethnographic insights can be paired with technical development.

Finally, the case of Qingpu underscores the challenge of balancing general lessons with contextual specificity. While certain infrastructural and policy dynamics resonate across rice-growing regions, the risk of standardized "one-solution" approaches is high. Future work should explore how circular strategies can be developed in ways that are both transferable and situated, building shared knowledge while respecting ecological and infrastructural particularities.

5. Conclusion: Toward an Architecture of Entangled Materials

This paper has examined the material life of rice husk and straw within the cultivation systems of Qingpu, approaching them not as inert residues but as substances embedded in ecological, technical, and political processes. By following these materials through seasonal cycles, infrastructural interactions, microbial

decomposition, and post-harvest practices, we have reframed their roles within agricultural and architectural contexts. Our findings suggest rice straw and husk are more than agricultural leftovers awaiting reuse; they actively shape multispecies worlds, influencing microbes, insects, birds, farmers, and designers alike. Their trajectories are conditioned by hybrid seed technologies, governmental yield targets, mechanized routines, and environmental regulations. Yet these materials resist complete capture, participating in decompositions and entanglements that complicate linear models of efficiency.

Rice production in Qingpu thus emerges not as a closed-loop system, but as a multispecies endeavor involving human and nonhuman collaborators—from machinery and water flows to microbial decomposers. The fields are not stable ecosystems but contested territories where narratives of food security and yield coexist uneasily with sustainability imperatives. Similarly, frictionless circularity—in which waste is seamlessly reintegrated—proves idealized and incomplete, marked instead by transformation, leakage, and negotiation.

For architecture, the challenge is not simply how to transform waste into resources, but how to inhabit existing material ecologies with care. This requires approaches that move beyond extractive innovation toward practices attuned to multispecies entanglement and situated knowledge. In this sense, sustainability begins not with new materials, but with new relationships. Future research could build on this by fostering collaboration between farmers, ecologists, and material scientists, exploring how design might support rather than override these entanglements, aligning architectural experimentation with ecological regeneration.

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