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Case Study Open Access

Study on the Application of Full-process Mechanization in Green and Efficient Production of High-quality Rice: A Case Study of Mashan Agricultural Service Center in Shangyu District

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Abstract This study explored the application of full-process mechanization in the green and efficient production of high-quality rice by taking Mashan Agricultural Service Center in Shangyu District, Zhejiang Province, as a practical case. Against the background of rapid agricultural modernization and increasing demand for green agricultural development in China, the study examined how regional agricultural service centers integrate mechanized seedling cultivation, machine transplanting, field management, plant protection, harvesting, drying, storage, and rice processing into a coordinated agricultural production system. Based on field materials, project documents, and operational cases, the study analyzed the service model, equipment configuration, production organization, and operational effects of the Mashan center. The results showed that full-process mechanization significantly improved rice production efficiency, reduced labor dependence, lowered grain losses during harvesting and postharvest stages, and enhanced the stability and quality consistency of high-quality rice production. In particular, centralized seedling cultivation, emergency mechanized harvesting during typhoon periods, and expanded grain drying capacity played important roles in strengthening regional food security and disaster-response capacity. The study also found that agricultural service centers can effectively bridge the gap between small-scale farmers and modern agricultural technology through socialized agricultural services. At the same time, several challenges remain, including high machinery investment costs, shortages of skilled technicians, uneven mechanization levels among farmers, and increasing climate-related risks. Therefore, future development should focus on improving regional agricultural service networks, strengthening agricultural talent training, promoting practical intelligent agricultural machinery, enhancing digital management, and extending the high-quality rice industry chain. The findings of this study provide practical references for promoting sustainable rice production and agricultural modernization in major rice-producing regions of China.

Keywords Full-process mechanization; High-quality rice; Agricultural service center; Green agricultural production; Rice mechanization

1 Introduction

Rice is not only a staple crop in China, but also a strategic crop closely tied to national food security, rural livelihoods, and regional agricultural modernization. A recent review of Chinese rice production showed that total rice output rose steadily from 2001 to 2021, and that the rise was driven largely by improvements in yield per unit area rather than by expansion of planted land. That long-term trend is encouraging, but it also means that future gains must come less from acreage growth and more from better organization, better varieties, and better management, especially in ecologically and economically advanced provinces where land and labor are both costly. Tang et al. (2022) further noted that rice production in China increasingly depends on coordinated improvements in varieties, field management, and agricultural resource use, rather than on one single input alone.

Yet the everyday reality of rice farming is still shaped by production bottlenecks. Recent studies on rice production efficiency in China indicate that mechanization and custom machine services already have measurable influences on technical efficiency, although the effects remain uneven across production stages and farm scales. The problem is not simply whether machinery exists, but whether farmers can access appropriate machinery and

integrated services at critical farming periods. Supporting services such as seedling cultivation, pest management, drying, storage, and transportation must be organized into a coordinated production chain. This issue is particularly important for small-scale farmers, who often cannot afford independent machinery investment but still require professionalized and standardized services to avoid yield and quality losses (Cai et al., 2024; Zeng et al., 2025).

The greening of rice production adds another layer to this challenge. Green agricultural production does not imply reducing mechanization; instead, it requires more precise and scientifically managed mechanized operations. Studies conducted in southern China demonstrated that agricultural socialized services can improve fertilizer-use efficiency and enhance technical performance among small rice farmers by lowering information barriers and increasing access to specialized agricultural knowledge. Other studies also showed that mechanization contributes not only to labor saving and output growth, but also to improvements in green grain productivity when combined with low-carbon production practices and trans-regional machinery coordination (Ma et al., 2023; Shi et al., 2023; Cai et al., 2024).

Zhejiang Province provides a particularly valuable context for this discussion. In 2024, Zhejiang Province issued policy guidelines encouraging the accelerated construction of modern agricultural service centers, aiming to establish a professionally managed agricultural service network by 2027. The policy emphasized full-process mechanized farming, centralized seedling cultivation, grain drying, digital agriculture, emergency agricultural response systems, and brand-oriented agricultural development as key directions for future modernization. At the local level, Shangyu District has been recognized for four consecutive years as a major grain-producing county in Zhejiang Province. According to the 2024 regional statistical communiqué, the district maintained approximately 483,200 mu of grain-sown area, while local government documents also identified Shangyu as a pilot area for rice machine-transplanting subsidy programs. These policy and production conditions make Shangyu an important case for understanding how regional agricultural service centers translate provincial modernization strategies into practical agricultural operations.

This study therefore focuses on one central question: how does a regional agricultural service center transform full-process mechanization into a practical model for the green and efficient production of high-quality rice? To answer this question, the study takes Mashan Agricultural Service Center as a representative case. The center is not treated as a universally perfect model, but rather as a practical operational example that helps translate abstract agricultural modernization policies into observable field practices. The study links recent research on agricultural mechanization and socialized agricultural services with a traceable local case involving seedling cultivation, mechanized field management, emergency harvesting, grain drying, processing, and rice brand development.

2 Overview of the Study Area and Agricultural Service Center

2.1 Basic situation of rice production in Shangyu District

Shangyu District is located in Shaoxing, in the economically dynamic and agriculturally intensive part of eastern Zhejiang. In such areas, rice production operates at the intersection of two strong forces. On one side, there is pressure from urbanization, labor transfer, and competition for land and labor. On the other, there is strong policy support for grain security, high-standard farmland, higher yields, better quality, and greener production methods. The district's 2024 development statistics reported 483,200 mu of grain-sown area and highlighted Shangyu's role as a grain-producing county, its machine-transplanting subsidy pilot work, and the establishment of large high-yield rice demonstration blocks. These facts suggest that Shangyu is not a marginal rice area, but a place where rice remains an important component of local agriculture and where policy attention to rice production is unusually strong.

Rice production in eastern China is also increasingly quality-oriented. Nationally, rice output growth has depended heavily on yield enhancement, but local consumers and public procurement systems now care not only about quantity, but also about eating quality, uniformity, safety, and market identity. Zhejiang's 2024 provincial notice on leading crop varieties and promoted technologies, together with its long-running "Zhejiang Good Rice"

selection program, reflects this shift from basic output protection to quality-centered, greener, and more branded rice development. In such a policy environment, high-quality rice production is best understood not as a niche activity, but as a mainstream direction for local grain agriculture.

The local rice landscape around Mashan combines relatively open paddy fields with infrastructure suited to mechanized operations. Level rice fields, irrigation ditches, road access along the field edge, testing plots for quality varieties, and nearby drying and service facilities. Full-process mechanization depends on field conditions, access roads, service dispatch capacity, and post-harvest facilities just as much as it depends on the machines themselves. In regions where fields are physically operable and service centers are close enough to dispatch machinery rapidly, the organizational value of mechanization increases sharply. This point is broadly consistent with studies showing that land conditions, service access, and operation scale jointly affect machinery utilization and production efficiency in Chinese rice systems (Wang et al., 2023).

2.2 Construction of mashan agricultural service center

Mashan Agricultural Service Center is located in Mashan Village, Shangyu District, and was built and is operated by the Shaoxing Shangyu Mashan Grain Specialized Cooperative. The project covers 6.73 mu and includes a drying center of 2,400 square meters, a seedling cultivation center of 1,888 square meters, and a machinery shed of 200 square meters. Total investment exceeded RMB 6 million. The center was designed with relatively clear functional zoning, including repair rooms, machine sheds, processing rooms, storage rooms, drying rooms, and training or meeting spaces. The same materials state that the center has seven fixed workers, around 100 sets of agricultural machinery and equipment, machine assets valued at roughly RMB 8 million, and a 100% licensing rate among machinery operators.

This basic profile matters for two reasons. First, it shows that the center is not a symbolic public building; it is a working service platform built around operational capacity. Second, it demonstrates a familiar but important principle in agricultural modernization: service centers succeed when they combine physical infrastructure, machinery, people, and organizational routines, rather than treating mechanization as a matter of equipment ownership alone. Zhejiang's 2024 policy on modern agricultural service centers explicitly stressed the need for coordinated functions such as full-process mechanized operation, centralized seedling cultivation, drying and processing, technical services, and training, and the Mashan center closely matches that policy logic in built form (Figure 1).

Figure 1 Aerial view of Mashan Agricultural Service Center and surrounding paddy landscape (Photoed by Xinfeng Ren)

The aerial image of the center reinforces this interpretation. The service buildings are embedded directly within a rice-producing landscape, with easy road access and visible proximity to operational fields. This spatial arrangement is part of the center's practical value. A center that sits close to its service area can move seedlings, machines, and harvested grain quickly, which is essential during narrow operation windows and emergency

weather periods. That operational closeness is also consistent with Zhejiang's larger goal of building a five-kilometer agricultural service circle so that support is delivered near the field instead of from distant, fragmented providers.

2.3 Main facilities and equipment configuration of the service center

Mashan's internal logic is structured around the most time-sensitive links in rice production: seedling cultivation, field operations, emergency harvesting, drying, storage, and simple processing. The center's original facilities included drying rooms, processing rooms, machine sheds, storage spaces, and a dedicated seedling center. A later expansion added 805 square meters of built area, eight more dryers, a 750-ton indoor metal granary, a 50-ton rice processing line, and additional service spaces needed for centralized seedling cultivation and machinery support.

This expansion raised the center's single-batch drying capacity to 400 tons and increased annual drying capacity from 10,000 tons to 18,000 tons. In practice, such post-harvest investment is one of the clearest signs that the center is operating as a full-chain rice service platform rather than as a simple machine dispatch unit. For high-quality rice, harvest is not the last decisive step. Drying conditions strongly affect the physical, processing, and nutritional quality of grain. Recent drying studies show that drying temperature, humidity, airflow, and moisture conditions influence cracking risk, whole-rice rate, germination quality, and postharvest stability, while scientific drying design can reduce losses and support quality retention (Li et al., 2024).

The center's equipment structure also reflects a service philosophy centered on coordination. Machinery and facilities are not isolated investments, but linked assets: centralized seedling equipment supports machine transplanting; harvest machinery feeds directly into drying; drying supports storage and processing; processing supports branding and marketing. This chain approach aligns with broader findings that agricultural mechanization becomes more productive when it is embedded in service systems rather than treated as a stand-alone farm input (Liu and Li, 2023; Ruan et al., 2025).

2.4 Service scope and service model for high-quality rice production

Mashan's service model as a "1+8" system built around full-process mechanized services and supported by drying and processing, centralized seedling cultivation, agricultural technical services, input delivery, machinery maintenance, agricultural study and training, product marketing, and storage and preservation. Four specialized teams have already been formed for mechanized operations, input delivery, technical services, and machinery repair.

They distinguish between a core neighboring service area and a broader regional service reach. The center provides "nanny-style" services for around 5,000 mu of nearby farmland and can deliver more than 50,000 mu-times of full-process mechanized services each year. The center provides integrated agricultural services to a 55,000-mu rice-and-wheat production area across seven surrounding towns and streets. Read together, these figures suggest a layered service pattern: intensive nearby support, combined with wider regional outreach through cross-village operation teams. Such a layered service structure is consistent with recent literature showing that service-scale operation and land-scale operation are complementary rather than mutually exclusive in promoting machinery utilization and reducing per-unit machinery costs (Zeng et al., 2025).

The service model is also important for how it deals with smallholder constraints. Smallholders do not necessarily need to own the entire set of modern inputs and machines. What they need is dependable access to those inputs and operations at the right time, with predictable service quality and reasonable cost. The best recent work on agricultural socialized services in China argues that these services matter most where they reduce timing constraints, improve technology accessibility, and bridge the organizational gap between small-scale farming and modern agricultural systems. Mashan's "service center + specialized teams + nearby and regional operations" model fits that logic closely (Cai et al., 2024; Zeng et al., 2025).

3 Application of Full-process Mechanization in Green and Efficient Production of High-quality Rice

The key value of full-process mechanization lies in coordination across production stages. A rice production

system becomes truly “full-process” only when the earlier stages are designed to support the later ones, and when grain quality is protected from seedling cultivation to post-harvest handling (Table 1). In the Mashan case, the service center does not function as a loose collection of separate services, but as an integrated chain in which field timing, machine scheduling, seedling quality, drying capacity, and technical guidance support one another.

Table 1 Full-process mechanization chain in high-quality rice production

Link	Main practice at Mashan	Main contribution
Centralized seedling cultivation	Unified nursery preparation and tray seedling supply	More uniform seedlings and lower household labor demand
Mechanized transplanting	Timely transplanting through service teams	Reduced labor bottlenecks and more standardized planting
Mechanized field management	Organized water, fertilizer, and technical guidance	Easier adoption of standardized management
Green plant protection	Scaled plant protection and technical support	Lower missed-control risk and more targeted pest management
Combine harvesting	Rapid harvester dispatch during peak season	Better timeliness and lower field losses
Grain drying and processing	Centralized drying, storage, and rice processing	Lower postharvest loss and better quality retention

This framework is consistent with recent studies on rice mechanization, which increasingly emphasize that labor saving alone is not enough. Seedling supply, service accessibility, harvest timing, drying control, and postharvest organization are all important in determining whether mechanization can improve rice production in a stable and environmentally reasonable way (Liu and Li, 2023; Li et al., 2024; Ruan et al., 2025).

3.1 Mechanized application of centralized rice seedling cultivation

Centralized seedling cultivation is the first key threshold in many machine-transplanted rice systems. If seedlings are weak, uneven, or not available on time, later mechanized operations lose part of their value. Recent research on machinery rice transplanting and centralized rice seedling cultivation in China shows that modern seedling centers do more than save labor. They improve seedling supply efficiency, raise the use efficiency of nursery space, and make large-scale machine transplanting easier to organize (Ruan et al., 2025).

The Mashan materials show this logic clearly. The center includes a dedicated seedling cultivation area and provides more than 200,000 trays of early- and late-rice seedlings annually for local farmers. The project materials also report that technical guidance associated with the center helped improve seedling establishment rates for surrounding farmers by about 20%. Although these figures are operational records rather than controlled experimental data, they still show a practical point: standardized seedlings are one of the most direct ways to improve later field performance.

This stage also has a green-production meaning. Centralized seedling cultivation can reduce repeated household-level preparation, lower waste in nursery materials, and make seed treatment and early-stage management easier to standardize. More importantly, it creates the basic condition for timely transplanting. Delayed or uneven transplanting often leads to uneven tillering, uneven maturity, and later problems in water control, pest prevention, and harvesting. By contrast, centralized seedling supply supports more synchronized crop growth, which is especially valuable in quality-oriented rice production.

3.2 Mechanized rice transplanting and field management

Mechanized transplanting is one of the most visible signs of modern rice production in eastern China, but it should be understood as a service system rather than only a machine operation. Shangyu’s local policy documents in 2024 clearly aimed to improve the local machine-transplanting rate through targeted subsidy support, indicating that machine transplanting is not only a farm-level choice but also a district-level policy priority.

In the Mashan case, machine transplanting is embedded in organized service delivery. The center’s mechanized operation teams provide field services across nearby and broader regional rice areas, reducing the need for farmers

to coordinate seedling transport, machine booking, and field labor by themselves. The practical gain is not only labor substitution, but also the reduction of uncertainty and delay. Research on rice production efficiency in China has shown that mechanization affects production efficiency differently across cultivation stages, and that its benefits are stronger when service access and operation timing are reliable (Shi et al., 2021).

Field management in a full-process system also becomes easier once transplanting is standardized. Uniform transplanting density and timing allow more consistent irrigation, fertilizer scheduling, and pest monitoring. In this sense, mechanized transplanting works as an organizational bridge between pre-production and in-season management. The Mashan materials further indicate that the center organizes technical training and expert guidance, especially during periods of high pest pressure. This suggests that field management is treated not as a purely mechanical issue, but as a combined agronomic and service task.

3.3 Green pest control and mechanized plant protection

Green pest control is sometimes misunderstood as the opposite of mechanized plant protection. In practice, the two can support each other when operations are timely, targeted, and professionally managed. Rice fields are highly sensitive to missed control windows, especially under humid and high-risk conditions. Small farmers working alone may delay control because of labor shortage, equipment limitations, or uncertainty about when and how to act. Agricultural socialized services can reduce these bottlenecks by making both technical advice and field operations more accessible (Shi et al., 2023).

The Mashan materials report that the center regularly organizes technical exchanges and invites district-level machinery and agronomy experts to provide field guidance during periods of frequent pest occurrence. More than 20 training sessions had been organized, and pest diagnosis and control had covered more than 5,000 mu. These details suggest a service model in which green plant protection is not limited to pesticide application, but includes diagnosis, timing, technical instruction, and operation support.

Recent research on UAV-based herbicide application in direct-seeded rice found that UAV systems could achieve weed control effects comparable to conventional knapsack systems under suitable conditions, while reducing labor burden and operator exposure (Paul et al., 2024). This finding should not be applied mechanically to every rice production context, but it supports a broader principle: plant protection can become greener when application is more precise and professionally managed.

For a service center like Mashan, the green value of mechanized plant protection lies mainly in timeliness, standardization, and risk reduction. Timely intervention helps avoid later over-application caused by delayed action. Standardized service can reduce variation caused by different farmers using different equipment and habits. Professionalized service also lowers the barrier to adopting improved control methods. In this sense, “green” means better organized and more accurate input use, not simply less machine use.

3.4 Application of mechanized rice harvesting

Harvest is the stage where yield, labor, weather, and grain quality meet most directly. Rice can tolerate some management imperfections during the growing season, but harvest delays under rain, typhoon conditions, or limited machine access can quickly lead to lodging, high-moisture grain, shattering, quality decline, and grain loss. This is why harvest is a central test of whether full-process mechanization works in practice.

The literature is clear on this point. A review of rice harvest losses shows that losses occur not only during reaping, but throughout the harvest process, including threshing, winnowing, transportation, and storage transfer. Poor harvest management, inappropriate techniques, and weak infrastructure all contribute to those losses (Qu et al., 2021).

For Mashan, mechanized harvesting is one of the center’s most visible strengths. The internal materials report that during the overlap of the “double rush” farming season and typhoon weather, the center deployed more than 20 harvester operations for emergency early-rice harvesting, completed urgent harvesting on more than 12,000 mu, and dried more than 14,000 tons of grain afterward (Figure 2). These figures do not represent a controlled experiment, but they clearly demonstrate operational capacity during a period when timeliness matters most.

Figure 2 Combine harvesting in the rice fields served by Mashan Agricultural Service Center (Photoed by Xinfeng Ren)

The field photograph of combine harvesters operating in the paddy landscape makes the service-center logic visible. In good weather, mechanized harvesting improves labor efficiency. In bad weather, it becomes a risk-management tool. A center able to quickly mobilize harvesting capacity across several towns is not only improving efficiency, but also performing a quasi-public service by protecting grain from weather shocks. Zhejiang's 2024 policy on modern agricultural service centers also encouraged centers to build emergency response teams and integrate them into local agricultural disaster-response systems, and Mashan's emergency harvesting case fits that policy direction closely.

3.5 Mechanized grain drying and processing

For high-quality rice, harvest without drying is incomplete mechanization. Grain that is harvested on time but not dried promptly may still suffer quality and safety losses. Drying affects grain cracking, storage stability, whole-rice rate, appearance, and later processing performance. Recent studies on rice drying have shown that carefully controlled drying conditions can improve both drying efficiency and grain quality, while poor drying management can quickly weaken the advantages of timely harvesting (Li et al., 2024).

The Mashan case gives drying a central place in the production chain. According to the internal project materials, the center added eight dryers after expansion and raised batch drying capacity to 400 tons, while annual drying capacity increased from 10,000 tons to 18,000 tons. The center also expanded grain storage through a 750-ton indoor metal granary and built a 50-ton rice processing line (Figure 3). These facilities make it possible to move from field rescue to stable postharvest management, and then from postharvest management to value-added rice products.

This stage is especially important in regions with narrow harvest windows and unstable autumn weather. Centralized drying reduces dependence on household sun drying, which is weather-sensitive, land-intensive, and difficult to standardize. It also supports grain safety, reduces the risk of mildew and quality deterioration, and creates the condition for processing and branding. In quality-oriented rice systems, this is a major bridge between agricultural production and the consumer market. Mechanized drying is therefore not simply a postharvest convenience. It is an essential part of green and efficient production because it prevents avoidable loss of grain already produced with limited land, water, energy, and labor resources (Qu et al., 2021; Li et al., 2024).

4 Promotion Effects of Full-process Mechanization on High-quality Rice Production

4.1 Improvement of rice production efficiency

The most immediate effect of full-process mechanization is improved production efficiency, but the term "efficiency" deserves a broader reading. It certainly includes speed and labor saving. Yet in rice production it also includes the ability to complete operations within the proper agronomic window, to reduce coordination failures, and to maintain service continuity across production stages. Research on Chinese rice production has shown that mechanization and custom machine services are positively associated with production efficiency, while empirical work on grain production capacity more broadly has shown that mechanization can improve both output capacity and production efficiency (Shi et al., 2021; Liu and Li, 2023).

Figure 3 Grain drying line and postharvest facilities at Mashan Agricultural Service Center (Photoed by Xinfeng Ren)

In Mashan's case, the efficiency effect appears not only in machine deployment, but in service organization. The center provides specialized teams, centralized seedlings, coordinated field operations, rapid harvest dispatch, drying, storage, and simple processing. That integrated structure lowers the number of separate transactions farmers must manage by themselves. It also reduces the risk that one weak link will delay the next. For example, the value of machine transplanting rises when seedling supply is standardized; the value of harvesting rises when drying capacity is immediately available; and the value of production increases when technical guidance accompanies physical operations.

Recent studies from southern China suggest that agricultural socialized services raise technical efficiency among smallholder rice producers and can improve grain yield per unit area through pathways such as greater machinery use, more moderate scale operation, and more grain-oriented planting structure. These mechanisms are particularly relevant to Mashan, which operates through both nearby "nanny-style" services and broader regional service provision (Cai et al., 2024; Liao et al., 2025).

4.2 Enhancement of high-quality rice production quality

High-quality rice production depends on more than high yield. It requires good seedlings, orderly field development, timely harvest, sound drying, and stable postharvest handling. In recent years, rice research has increasingly emphasized this combination of yield, grain quality, process quality, and consumer quality. Tang et al. (2022) linked long-term improvements in Chinese rice production to coordinated advances in varieties and management, while Li et al. (2024) showed that drying conditions shape processing and nutritional outcomes.

Mashan's mechanized chain supports quality in several ways. Centralized seedling cultivation improves the consistency of field establishment. Mechanized transplanting makes crop growth more uniform. Technical guidance helps farmers respond more quickly to pest pressure. Combine harvesting reduces delays at maturity. Centralized drying reduces the instability of household sun drying and better protects grain at high moisture. Finally, a local processing line makes it easier to turn paddy into a recognizable rice product under local brand management.

The center's internal materials further report that the registered "Xinfeng" rice brand won the Silver Award in the 2024 "Zhejiang Good Rice" competition. Even though the branding result itself is not a scientific measure, it is meaningful in an applied production study because it suggests that mechanized service capacity is being connected to quality recognition in the marketplace. Zhejiang's official rice-brand promotion program also shows that the province evaluates rice not just on output, but on physicochemical quality, eating quality, safety indicators, and the traceability of production processes. Viewed in that light, Mashan's brand result is best understood as the downstream expression of upstream production standardization.

4.3 Reduction of production costs and grain losses

The economic value of mechanization should not be measured only by lower labor input per hectare. In many rice regions, the larger gain comes from replacing uncertain, fragmented, or delayed operations with reliable service. Smallholders often cannot justify separate investment in nurseries, transplanting machinery, dryers, storage, and processing facilities. Service centers lower that barrier by spreading fixed costs across a larger service area. This is one reason agricultural socialized services matter so much in Chinese smallholder systems. They do not eliminate smallholders; they lower the cost of connecting them to modern agriculture (Zeng et al., 2025; Liao et al., 2025).

Loss reduction is equally important. Qu et al. (2021) showed that rice losses accumulate across the harvest process, including reaping, threshing, winnowing, transportation, and storage transfer. In a service-center context, grain loss is reduced not only because machines are faster, but because operations are organized in sequence. Prompt harvesting followed by immediate drying is far more effective than improving either link alone.

Mashan's emergency harvest case illustrates this clearly. The center did not merely send harvesters into the field; it paired harvest rescue with large-scale drying. That combination matters, especially under typhoon conditions, when wet grain can deteriorate rapidly after harvest. The center's expansion from 10,000 tons to 18,000 tons of annual drying capacity also suggests that the operators understood postharvest loss reduction as a core public and economic function, not as a secondary activity. In applied terms, this is one of the strongest arguments for full-process rather than partial mechanization: effective systems reduce both visible labor costs and less visible losses.

4.4 Promotion of green agricultural development and resource utilization efficiency

Green agricultural development is often discussed in broad policy language, but at farm scale it usually depends on a few concrete conditions: reducing unnecessary input use, improving operational precision, lowering waste, avoiding weather-related loss, and organizing production in ways that use land, labor, and machinery more efficiently. In rice systems, agricultural socialized services have been shown to encourage greener behavior among smallholders, while broader work on grain systems in China suggests that mechanization can support improved grain production capacity and resource-use efficiency when it is combined with organized services and coordinated operations (Liu and Li, 2023; Shi et al., 2023).

There is also emerging agronomic evidence that some mechanized rice cultivation systems can align productivity with environmental goals. A recent field study from the Taihu Lake region found that rotary tillage plus mechanical transplanting produced higher and more stable rice productivity while maintaining lower methane emissions and lower yield-scaled global warming potential than plowing plus mechanical transplanting. The exact agronomic conditions of that experiment differ from those at Mashan, but the broader implication is important: mechanization and greener outcomes are not inherently contradictory. The outcome depends on how tillage, planting, timing, and management are combined.

In Mashan, the green effect of full-process mechanization appears through organization. Centralized seedling production avoids repeated household-level preparation. Mechanized transplanting improves timeliness. Technical service encourages more standardized field management. Professionalized plant protection makes it easier to target inputs. Combine harvesting and centralized drying reduce avoidable loss of grain already produced. Storage and processing prevent further postharvest waste and create a traceable pathway to market. Green development in this sense is not a separate project added after mechanization. It emerges when mechanization is used to raise the efficiency of the whole chain and to reduce wasted labor, wasted grain, and wasted operations.

5 Case Analysis of Mechanization Application in Mashan Agricultural Service Center

Before discussing the individual cases, one limitation should be stated clearly. The four cases below are based mainly on two internal project briefs supplied with the manuscript materials and on field photographs (Table 2). These are operational management materials rather than independently audited datasets. They are therefore used here as descriptive case evidence, not as a statistical basis for causal inference. Their value lies in showing how the center works in practice.

Table 2 Core operational cases from Mashan Agricultural Service Center

Case	Main content	Practical significance
Centralized seedling cultivation services	More than 200,000 seedling trays supplied annually; technical guidance reportedly improved seedling establishment by about 20%	Strengthens the basis for machine transplanting and reduces household nursery burden
Emergency mechanized harvesting during "double rush"	More than 20 harvester operations deployed; over 12,000 mu harvested; over 14,000 tons dried	Demonstrates disaster-response and harvest-loss-reduction capacity
Grain drying capacity improvement	Eight dryers added; batch capacity raised to 400 tons; annual drying increased from 10,000 to 18,000 tons	Converts mechanized harvesting into stable postharvest management
High-quality rice brand development	"Xinfeng" rice won Silver Award in "Zhejiang Good Rice 2024"	Connects mechanized services with local branding and value-added products

5.1 Case of centralized seedling cultivation services

The centralized seedling cultivation case is important because it shows how a service center can intervene at the earliest and often most fragile stage of rice production. According to the case materials, Mashan relies on its seedling cultivation center and mechanized sowing arrangements to provide unified seedling services for surrounding farmers, supplying more than 200,000 seedling trays annually. This is not a small support activity attached to the center. It is one of the enabling conditions of full-process mechanization.

The practical effect of such a service is straightforward. Farmers who receive standardized tray seedlings do not need to manage seedling preparation individually at household scale. That lowers labor requirements, reduces technical unevenness across farms, and makes machine transplanting easier to schedule. The internal materials further note that technical guidance linked to the center helped raise seedling establishment rates by around 20%, which suggests that the service is not purely material supply, but a combination of production input and agronomic support.

This case also reflects conclusions from recent agricultural mechanization studies. Research has shown that centralized seedling cultivation not only supports machine transplanting but also improves seedling-field efficiency and helps release land and labor resources under crop rotation systems (Ruan et al., 2025). In the Mashan case, the local lesson is simpler but equally important: professionalized seedling supply makes later mechanized stages more reliable and improves the overall rhythm of rice production.

5.2 Case of mechanized emergency harvesting during the "Double Rush" period

Among the four cases, the emergency harvesting case most clearly demonstrates the social value of regional agricultural service centers. During the overlap of the "double rush" farming season and typhoon weather, Mashan mobilized more than 20 harvester operations, completed emergency harvesting on more than 12,000 mu of early rice, and carried out more than 14,000 tons of grain drying afterward. The combination of harvesting and drying is especially important.

What makes this case analytically meaningful is not only the scale, but also the timing. During normal years, mechanization improves production efficiency. During abnormal years, it protects grain that has already been produced. Research on rice harvest losses repeatedly emphasizes that poor harvest management and weak infrastructure can significantly increase grain losses, while timely harvesting is one of the most important conditions for effective loss reduction (Qu et al., 2021). The Mashan case transforms this general conclusion into a concrete operational example. Harvesting machines alone would not have solved the problem. Without sufficient drying capacity, much of the rescued grain would still have remained vulnerable under humid conditions.

This case also aligns closely with Zhejiang Province's agricultural modernization policy. Zhejiang's 2024 policy documents specifically encouraged modern agricultural service centers to establish emergency operation teams and participate in regional agricultural disaster-response systems. Therefore, Mashan's emergency harvesting

activities should not be viewed simply as a temporary operational success. Instead, they represent the kind of regional resilience function that current agricultural policy increasingly expects from modern service infrastructure.

5.3 Case of grain drying capacity improvement

The drying-capacity expansion case demonstrates that the development path of the Mashan center gradually moved from basic agricultural service provision toward stronger postharvest management capacity. According to the project materials, the center added eight grain dryers during expansion, increasing single-batch drying capacity to 400 tons and annual drying capacity from 10,000 tons to 18,000 tons. The center also added a 750-ton indoor metal grain warehouse and a 50-ton rice processing line.

This case matters because drying is one of the clearest dividing lines between partial mechanization and full-process mechanization. A mechanized production system without adequate drying facilities still faces substantial quality and storage risks. High-moisture grain cannot remain untreated for long periods under humid climatic conditions. Furthermore, for high-quality rice, standardized drying is itself an important part of quality preservation. Recent drying studies have shown that better control of drying process parameters can improve the balance between drying efficiency and grain quality retention (Li et al., 2024).

The practical importance of Mashan's drying expansion is therefore twofold. First, it strengthens regional grain-loss reduction and grain-storage security capacity. Second, it makes downstream rice processing and branding more reliable. Quality-oriented rice production requires consistency not only in the field, but also after harvest. By expanding drying and storage capacity, the center created a stronger bridge between emergency harvest rescue, grain quality retention, and value-added rice products.

5.4 Case of high-quality rice brand development

The fourth case extends the analysis from agricultural production and service provision to market value creation. The internal project materials state that Mashan registered the "Xinfeng" rice brand, and that the brand won the Silver Award in the "Zhejiang Good Rice 2024" competition. Although this result is not a production indicator in the narrow agronomic sense, it remains a meaningful applied outcome. A service center that can supply seedlings, organize mechanized operations, coordinate drying, and process grain is naturally in a stronger position to support stable branded rice products than a service provider limited only to field operations.

The significance of this case becomes clearer when viewed within Zhejiang's provincial rice-branding framework. The "Zhejiang Good Rice" program evaluates rice not only on yield, but also on grain quality, eating quality, safety indicators, and standardized production records. In other words, brand recognition is closely tied to production organization and traceability rather than marketing language alone. Under such a policy environment, the Mashan case suggests that full-process mechanization can contribute not only to production efficiency and grain-loss reduction, but also to the market differentiation and added value of locally produced high-quality rice.

More broadly, this case reflects a larger transition in the role of regional agricultural service centers. Their function is no longer limited to "helping farmers complete field operations." Increasingly, they are also becoming important platforms for product upgrading, local branding, and value-chain extension. This transition is particularly important in developed eastern provinces, where agriculture often needs to rely on quality, service integration, and branding rather than low-cost bulk production alone.

6 Current Problems

6.1 High investment costs of advanced agricultural machinery

One of the clearest constraints revealed by the Mashan case is the high capital intensity required for full-process mechanization. The internal materials describe more than RMB 6 million in project investment, around RMB 8 million in machinery assets, as well as large-scale drying facilities, nursery infrastructure, grain storage systems,

and a rice processing line. Although this structure provides strong operational support for modern rice production, it also explains why many smaller organizations and ordinary farming households cannot easily replicate such a model independently.

Existing research supports this concern. Studies on agricultural mechanization and grain production efficiency in China have repeatedly shown that although machinery can improve productivity and operational efficiency, high acquisition and upgrading costs remain major barriers, especially in regions characterized by small farm sizes and uncertain returns (Liu and Li, 2023; Li et al., 2024). Advanced grain dryers, intelligent transplanting systems, plant-protection machinery, and digital management equipment require not only initial investment, but also continuous expenditures for maintenance, fuel, electricity, repair, and replacement.

For Mashan Agricultural Service Center, this means that future development depends on maintaining a balance among policy support, service income, and operational scale. If service demand decreases, it becomes more difficult to absorb high fixed costs. Conversely, if machinery technology upgrades too quickly relative to local service revenues, the center may face financial pressure despite maintaining advanced equipment. Therefore, capital intensity is not simply an issue of investment; it is also a long-term issue of operational sustainability.

6.2 Shortage of professional agricultural machinery technicians

The Mashan materials indicate that the center currently employs seven full-time workers and maintains a 100% certification rate among machinery operators. While this reflects a relatively standardized management structure, it also reveals an important vulnerability. A limited number of technical personnel are expected to support multiple services simultaneously, including seedling cultivation, machinery dispatching, machinery maintenance, pest-control coordination, grain drying, storage management, and farmer training.

As agricultural service systems become more integrated and digitalized, the demand is no longer limited to machine operators alone. Service centers increasingly require multi-skilled technicians capable of managing scheduling systems, field operations, equipment repair, drying control, safety supervision, operational records, and digital agricultural platforms.

This issue has already been recognized in recent agricultural modernization research. Studies on smart agricultural machinery and digital farming systems show that many service organizations still face barriers related to technical training, digital literacy, management ability, and operational competence (Gong et al., 2024; Hashim et al., 2024; Li et al., 2024). The effectiveness of advanced agricultural machinery does not depend solely on subsidies or equipment ownership. It also depends heavily on whether operators and service personnel can use the technology effectively under practical farming conditions.

For Mashan, this suggests that human-resource limitations may become the next major bottleneck after machinery investment. Even well-equipped service centers may struggle to achieve their expected efficiency if they lack enough qualified personnel capable of operating, maintaining, and coordinating modern agricultural systems. As the center moves toward more quality-oriented and digitalized production models, the importance of technical talent will continue to increase.

6.3 Differences in mechanization levels among small-scale farmers

Although regional agricultural service centers can reduce inequality in technology access, they cannot completely eliminate differences among farmers. In practice, smallholder farms still differ greatly in land fragmentation, road accessibility, irrigation conditions, willingness to pay for services, awareness of quality-oriented production, and acceptance of standardized farming management.

Research on agricultural socialized services in China has consistently shown that service outcomes vary according to regional conditions, land fragmentation levels, and household characteristics. Farmers with stronger production orientation, lower land fragmentation, or higher digital capability often benefit more quickly from mechanized services (Liao et al., 2025; Zeng et al., 2025).

This issue is particularly relevant in the Mashan case because the center serves both nearby villages and a broader multi-township agricultural region. As the service radius expands, the center inevitably encounters greater variation in field conditions and farmer demands. A single standardized service package may therefore not suit all users equally well. Some households may only purchase harvesting services, while others may accept partial or full-process trusteeship services. Some farmers prioritize quality-oriented branded production, whereas others focus mainly on reducing immediate production costs.

These differences indicate that full-process mechanization still has organizational and social boundaries. Even when machinery services are available, farmer adoption depends on factors such as trust, land conditions, production goals, and the suitability of service arrangements. Therefore, agricultural service centers must function not only as technical providers, but also as coordinators capable of matching different farmers with appropriate service combinations.

6.4 Significant impacts of extreme weather on rice production

The Mashan emergency harvesting case clearly demonstrates that extreme weather remains a major challenge even in relatively well-equipped agricultural regions. Rice production in China is increasingly exposed to climatic uncertainty, including heat stress, heavy rainfall, typhoon events, and humid harvesting conditions. Recent climate-related studies suggest that extreme climate events may become more frequent and more severe in future rice production systems, particularly under warming scenarios that intensify heat stress and increase production instability (Jiang et al., 2025).

For agricultural service centers, extreme weather creates several interconnected challenges. It shortens operational windows, increases pressure on machinery scheduling, raises demand for emergency drying and temporary storage, and may generate sudden service demand beyond ordinary operational capacity. Mashan's ability to organize emergency harvesting and large-scale drying during the "double rush" period was impressive, but the case also reveals how quickly even well-organized systems can be placed under stress during abnormal climatic conditions.

This challenge is unlikely to disappear in the future. Modern agricultural service centers will increasingly be evaluated not only by their efficiency during normal seasons, but also by their resilience during periods of climatic disruption. Full-process mechanization improves regional response capacity, but resilience itself must now become an explicit goal in the design of agricultural modernization systems.

7 Optimization Suggestions and Development Directions

7.1 Improving the regional agricultural machinery service system

The Mashan case suggests that the future development of agricultural mechanization depends not simply on increasing the number of machines, but on strengthening the regional agricultural service system itself. Zhejiang Province's 2024 policy already reflects this direction by emphasizing layered service networks, comprehensive functional coverage, and the establishment of a five-kilometer agricultural service circle. For service centers such as Mashan, the practical implication is the establishment of clearer service zoning, including a nearby core area for highly intensive "nanny-style" services, a broader operational area for scheduled cross-township services, and an emergency-response layer designed for extreme weather and urgent harvesting tasks.

Recent research also supports stronger integration of agricultural service systems. Studies on agricultural socialized services show that service efficiency is highest when mechanized operations improve production continuity, operational coordination, and machinery utilization across different stages of farming (Cai et al., 2024; Liao et al., 2025). Instead of expanding services randomly, agricultural service centers should strengthen the links among seedling cultivation, transplanting, plant protection, harvesting, drying, transportation, and storage so that farmers can rely on one coordinated operational chain rather than fragmented service providers.

For Mashan, this may involve establishing more stable long-term service agreements with nearby villages, improving seasonal booking systems, and strengthening coordination among grain ordering, drying demand, and

emergency operation planning. The long-term objective is not merely to remain a capable service provider, but to become a stable regional agricultural operation hub.

7.2 Strengthening agricultural machinery training and talent cultivation

Machinery-centered modernization cannot be sustained if talent development falls behind infrastructure construction. Mashan Agricultural Service Center already provides technical guidance and training spaces, which creates a strong foundation for future development. However, the next step should be to shift from occasional training activities toward a more systematic and layered talent cultivation framework.

Current research provides clear evidence for the importance of training and technical capacity building. Studies on smart agricultural machinery adoption and digital agricultural transformation indicate that technology adoption depends heavily on practical training, demonstration effects, operator confidence, and digital literacy (Gong et al., 2024; Hashim et al., 2024; Li et al., 2024). Advanced machinery alone cannot improve agricultural modernization unless users understand how to operate, maintain, and coordinate the technology effectively under real production conditions.

For Mashan, a tiered training system would be particularly useful. The first level should focus on safe and standardized machinery operation. The second level should emphasize quality-oriented field management, drying control, and postharvest handling. The third level should target younger agricultural workers, cooperative members, and local service-team leaders who are capable of combining agricultural technology with management and digital skills. Such a training structure would also align closely with Zhejiang Province's policy emphasis on cultivating practical agricultural talent through modern agricultural service centers.

7.3 Promoting green and intelligent agricultural machinery

The future green transformation of rice production increasingly depends on "intelligent enough" agricultural machinery rather than simply larger machinery. For Mashan Agricultural Service Center, the key issue is not whether to adopt intelligent technologies, but which technologies provide the highest practical value under local production conditions.

Recent research provides several important directions. Studies on UAV-based plant protection show that precision spraying systems can improve operational timeliness, reduce labor burden, and lower operator exposure while still maintaining effective pest-control performance under suitable conditions (Paul et al., 2024). Smart-farming studies in rice production also emphasize the value of integrating sensors, IoT systems, and digital decision-support tools into irrigation management, crop monitoring, and quality management systems (Hashim et al., 2024). In addition, grain-drying research has shown that improved drying-control systems can significantly improve grain quality retention and reduce postharvest losses (Li et al., 2024).

For Mashan, the most appropriate strategy is therefore to prioritize "practical intelligence" rather than blindly pursuing expensive technologies with limited local applicability. In practical terms, technologies that directly improve operation timing, quality consistency, or grain-loss reduction should receive priority. Precision plant-protection equipment, drying parameter monitoring systems, and machinery scheduling platforms are likely to provide more immediate value than highly complex systems that require excessive investment and technical support.

7.4 Enhancing digital and information-based management

If the first stage of modern agricultural service center development focused mainly on physical infrastructure construction, the second stage increasingly focuses on digital and information-based management. Zhejiang Province's 2024 agricultural modernization policy explicitly encourages integration with provincial digital agriculture platforms and supports the establishment of online-offline integrated agricultural service systems. This policy direction is particularly relevant for Mashan because the center already manages multiple agricultural functions across a relatively large regional service area.

Digital management can significantly improve coordination among seedling supply, machinery dispatch, harvesting schedules, drying queues, service records, and grain traceability systems. Recent studies on digital agricultural service systems show that digital tools can increase farmers' willingness to adopt modern agricultural technologies by improving information accessibility, strengthening technical understanding, and reducing communication barriers (Gong et al., 2024). Smart-farming research in rice systems likewise demonstrates that digital technologies are becoming increasingly important for crop monitoring, yield estimation, classification management, and production decision support (Hashim et al., 2024).

For Mashan, digital transformation does not necessarily need to begin with highly complex artificial intelligence systems. A more practical approach would be to begin with relatively simple but operationally useful digital tools, including online booking systems for transplanting and harvesting, machinery scheduling records, drying-batch monitoring, grain traceability systems, and farmer service databases. Once these systems become stable and widely accepted, the center could gradually expand toward more advanced digital support systems for quality management, emergency coordination, and regional agricultural decision-making. In high-quality rice production systems, traceability itself has already become an important source of product value.

8 Conclusion

This study used Mashan Agricultural Service Center in Shangyu District as a practical case to examine how full-process mechanization can support the green and efficient production of high-quality rice. The case shows that the real strength of full-process mechanization does not lie in any single machine or single operation. Its strength lies in coordination. When centralized seedling cultivation, machine transplanting, organized field management, plant protection, combine harvesting, grain drying, storage, and simple processing are linked into one service system, rice production becomes more timely, more stable, and better able to protect both yield and quality.

The Mashan experience also shows that regional agricultural service centers have become important institutions in the modernization of rice production. They reduce barriers facing small farmers, expand access to modern technology, improve emergency response during extreme weather, and create the practical conditions for branded high-quality rice development. The center's case is especially valuable because it connects policy goals with operational reality: it demonstrates how a local service platform can turn broad ideas such as green production, socialized service, and agricultural modernization into concrete field practices.

At the same time, the case makes clear that further progress will depend on solving several structural problems, including high capital costs, shortage of professional technicians, unequal service uptake among farmers, and weather-related risk. For that reason, the future direction of Mashan and similar centers should emphasize stronger regional service networks, training-oriented talent cultivation, useful intelligent equipment, digital management, and deeper integration of the rice industry chain. If these directions are pursued steadily, full-process mechanization can continue to serve not only as a labor-saving production model, but also as a realistic pathway toward higher quality, lower loss, greener operation, and more resilient rice agriculture.

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