Article



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# Organic Rice Transition in a Changing Environment: Linking Farmers' Benefits to Adaptation and Mitigation

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**Abstract**

Organic rice farming (ORF) is can support both climate change mitigation and adaptation. However, a deeper understanding of its specific benefits and challenges is needed. This paper synthesises current knowledge on the potential of ORF to enhance resilience in regions exposed to natural hazards, with particular attention to the climate-vulnerable region of the Mekong Delta (MKD), Vietnam. ORF can deliver multiple benefits: reducing production costs, revitalising degraded and pesticide-contaminated soils, improving water and soil quality, enhancing biodiversity, and contributing to human health and sustainable livelihoods. In the MKD context, where rice production intersects with acute vulnerability to salinity intrusion, storms, and drought, ORF also presents opportunities for long-term adaptation by improving ecosystem health and reducing socio-ecological vulnerability. Despite these benefits, ORF remains limited in scale and impact due to the lack of integrated, landscape-level implementation strategies. Challenges like chemical contamination, limited access to certified organic inputs, and insufficient institutional and technical support leave many existing ORF initiatives vulnerable and constrain further expansion. To fully realise ORF's resilience and sustainability potential, more targeted research and policy attention are needed. An integrated governance approach that considers both biophysical and socio-economic dimensions is essential to support a meaningful and scalable transition to organic rice farming in climate-sensitive regions like the MKD.

**Keywords:** rice organic agriculture; transition; soil quality; water; biodiversity; health; income; institutions

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## 1. Introduction

Climate change and biodiversity loss threaten global livelihoods and food production, prompting calls for sustainable methods that stabilize yields, enhance co-benefits, and build resilience [1–3]. With food demand projected to rise by up to 56% by 2050 [4], climate models predict yield declines of up to 23% under severe scenarios [5]. Consequently, many countries promote transitioning from conventional to organic agriculture to strengthen food system resilience and community well-being [6–8]. Between 2000 and 2020, organic agricultural land expanded over 500%, and organic markets grew nearly eightfold [9]. Organic practices can boost biodiversity and mitigate greenhouse gas emissions, though effects vary by context and methods [10–12]. Understanding the benefits and trade-offs of organic transitions across diverse socio-ecological systems, especially vulnerable deltas, is crucial.

Despite growing adoption, scaling organic agriculture faces challenges including vested interests, weak policies, economic perceptions, social inertia and uneven input and market access [13,14]. These are compounded by limited awareness of organic agriculture's interconnected socio-ecological impacts, at both the policy and community level, particularly in regions like the MKD where large vulnerable populations reside. Conventional agrochemical-based agriculture remains dominant, supported by agribusiness, markets, technology, and policy [15]. However, decades of intensive agriculture in Asia have degraded soil fertility and yields, increasing reliance on synthetic fertilizers and pesticides [16]. While the Green Revolution improved productivity in some areas [17], it also caused negative environmental, social, and health consequences [18,19]. These concerns have driven some governments to promote organic agriculture as a sustainable development strategy to restore food production and foster resilient livelihoods amid climate change [20,21]. Organic farming's socio-economic and environmental resilience, especially in vulnerable rural areas, calls for holistic evaluation of its adaptive capacity.

In the ecologically sensitive MKD, rice cultivation profoundly impacts environment and health. Excessive fertilizer and pesticide use exceed national averages, contributing to nitrogen pollution in waterways and pesticide residues in food [22–32]. Intensive agriculture has also caused biodiversity loss, soil degradation, and significant greenhouse gas emissions, notably methane and nitrous oxide [33–35]. Agriculture, dominated by rice production, accounts for a large share of Vietnam's GHG emissions [36]. Biodiversity and natural habitats have declined due to intensified agricultural and water management [37]. Sustainable rice cultivation in Vietnam requires balancing economic objectives with conservation and ensuring socio-ecological resilience to climate change, biodiversity loss, and pollution [22].

This paper reviews the benefits and challenges of transitioning to organic agriculture under climate adaptation frameworks, drawing on a literature review and comparisons with our findings from the MKD. Finally, we discuss transition challenges and propose recommendations to scale organic rice farming and integrate diverse benefits into policy frameworks.

## 2. Materials and Methods

To understand the state of the art in assessing the diverse benefits of organic transition, literature was gathered from SCOPUS and Web of Science databases on organic agriculture, filtered by title and then abstract for relevant social and environmental impacts. Further papers were sourced through snowball sampling by reviewing the references of papers selected. Literature was also compiled using ChatGPT and DeepSeek AI tools with the search terms "organic rice agriculture", "organic rice farming", "transition to organic rice", "challenges of organic rice" and "ecosystem services in organic rice".

Grey literature and technical documents on the study topic were sourced from expert consultations with German and Vietnamese researchers in the OrganoRice project. Vietnamese language publications were sourced with similar terms, translated into Vietnamese, using Google Scholar and the University of Can Tho literature database.

They were completed by our own interview experience from five provinces in the MKD, representing a trajectory from the Cambodian border in the West to the sea shore in the East (to be published).

In parts of the text, Chat GPT has been used for English language editing the manuscript, to improve grammar and wording.

## 3. Results

### *3.1. Benefits of Organic Rice Farming*

#### 3.1.1. Reducing Environmental Impact of Weed and Pest Management

For rice farmers, weeds are a major production barrier, particularly in organic rice farming where managing intense crop–weed competition is challenging [38]. Weeds reduce yields by competing for water, light, and nutrients and by increasing crop vulnerability to pests and diseases [39,40]. Without chemical herbicides, organic systems rely on hand weeding, biological control, optimized habitat and water management, and crop rotation to suppress weeds [41–43]. Though more labour-intensive, these methods can lower costs and minimize environmental impacts compared to conventional agriculture [41].

Unlike conventional rice farms (CRF), pests and diseases are generally less problematic in organic systems due to healthier plants grown in nutrient-balanced soils [44,45]. Organic fields often suffer fewer pest outbreaks [46,47]. Organic fertilizers support growth while reducing pests like brown plant hopper, stem borer, leaf folder, blast and sheath blight [48]. Selecting resistant varieties is a cost-effective strategy but requires knowledge and may affect yields [45,49].

Organic pesticides, often plant-derived and locally sourced, offer crop protection with minimised environmental impacts and can reduce cost, as seen in West Java [50]. While is known that synthetic insecticides can disrupt natural biocontrol and enable new pest outbreaks [51,52], the broader ecological impacts of organic treatments remain under study. Research in India's Godavari delta showed that organic mulch (*Sesbania sp.*) effectively managed some pests while maintaining yields [53].

Enhanced biological pest control by increased numbers or diversity of natural predators can be supported by intercropping, e.g., by flower strips [42,54–56]. Predators like spiders and dragonflies are effective antagonists of pest insects [57], which can significantly boost rice yields and hence ecosystem services [58]. Among insects, Odonata have been widely used as bioindicators of insecticide impact, reflecting effects at both lethal and sublethal levels [59–61]. Farmers aware of beneficial species, recognising and making use of them can reduce pesticide reliance [62].

Effective pest management must integrate socio-ecological principles—biodiversity, host resistance, landscape ecology, and social dynamics—since human knowledge, perceptions, and decision-making shape outcomes from individual farmers to policymakers [45].

Mekong Delta context

Farmers in the MKD report that ORF approaches can work well to suppress weeds and pests while simultaneously being beneficial for rice crops. In An Giang province, the use of biologically-derived (as opposed to chemically-derived) organic fertiliser was linked to increased rice plant size and health, while simultaneously fostering the proliferation of natural predators controlling the spread of pests. In Thoai Son district, in particular, the use of organic fertiliser led to thick, large, green leaves less susceptible to damage [63]. In Bac Lieu province, experiments using organic fertiliser resulted in an increased rice plant vigour reducing pest pressures (e.g., rice blast incidence) [64]. In Dong Thap province, the implementation of mechanical weeding and organic fertiliser use has decreased the necessity for chemical treatments while enriching nutrient absorption by rice plants [65]. Reducing chemical inputs including inorganic Nitrogen-Phosphorus-Potassium (NPK) fertiliser also lowers pest risks as evidenced by a study performed in organic fields in Quang Tri province, which experienced minor (2-4%) leaf roller infestation versus 50-70% in conventional fields [66]. Alternatively, some farmers are using a combination of managing water levels, manual weeding and biocontrol organisms such as Trichoderma to effectively control weeds and diseases in ORF fields.

In line with the Vietnamese government's increasing interest in organic rice expansion as a way to achieve more sustainable agriculture [67], the promotion of natural pest control is also outlined in section 5.1.10 of the Vietnam National Standards for organic agriculture (Tiêu chuẩn Việt Nam) TCVN 11041-5:2018, which reflects the government's recognition of the viable benefits of organic

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approaches. Despite this, there is currently a limited amount of research on alternative approaches to chemical use to support farmers through their transition from conventional to organic farming [68].

3.1.2. Promoting Soil Health and Nutrient Management

Long-term use of organic residues on certified organic farms improves key physical, chemical, and biological soil health indicators by enhancing soil organic carbon (SOC), nutrient availability, and microbial activity [44,69]. However, outcomes vary. Amarasekara et al. [70] observed higher soil pH, organic matter, and cation exchange capacity under organic management, but lower available nitrogen and phosphorus. Thus, transitioning to organic rice farming can benefit soil health, though results are context-dependent, particularly on initial soil quality [46].

Soil organic matter (SOM) is central to soil health, influencing both physicochemical properties and biological processes [71–73]. Intensive farming without organic inputs depletes SOM and nutrients, undermining sustainability [74]. Organic rice systems, through compost, manure, cover crops, and biomass additions, improve nitrogen supply and SOM levels, leading to higher SOC, improved soil structure, water retention, and reduced bulk density [69,75]. Increased SOM enhances fertility and resilience over time. Organic practices significantly boost SOC compared to chemical fertilizers [47], with five-year trials in India showing SOC increases of 50–58%, along with rises in available N, P, and K stocks of 3–10%, 10–30%, and 8–25% respectively [76]. In regions like Lao PDR, where soils are low in fertility, SOM and N-availability, organic farming can be particularly beneficial [77]. Given SOM's susceptibility to rising temperatures, elevated atmospheric $CO_2$, and changes in soil water content, its increase also supports climate resilience [78].

Organic practices enhance nutrient cycling by relying on natural nutrient sources such as compost, manure etc., and crop rotations. Gradual SOM decomposition releases nutrients gradually, reducing leaching and hence eutrophication of neighbouring streams and lakes, and improving plant uptake. Applying both macro and micro nutrients through organic residue addition can provide optimum supply of biologically available nutrients in organic rice systems [38,69,79]. Studies in Bhutan and India reported increased total nitrogen and available phosphorus on all elevation levels [47,75]. Rice quality also benefitted—rice grain analysis showed a significant increase in Fe and Mn content when two or more organic amendments had been applied and in Zn and Cu content with combined application of three or four of the organic amendments [47]. In Ghana, N uptake improved significantly under organic nutrient amendments [80]. Enhanced enzyme activity linked to SOM boosts nutrient cycling [69], while long-term organic input can increase micronutrient levels stimulating the mineralisation of organic matter, reducing redox potential, and improving the overall soil environment [69,72].

The measurement of soil pH provides valuable insights on various factors that influence plant growth, such as the availability of nutrients, the behaviour of added nutrients, the level of salt, the degree of soil aeration, the composition of soil minerals, and the prevailing meteorological conditions in the region [81]. Unlike chemical fertilizers, compost and manure stabilize or raise soil pH, improving nutrient uptake and creating favourable growth conditions [69,72,73].

Contamination with heavy metals such as As, Cd, and Pb—stemming from industrial waste, mining, pesticides, wastewater irrigation, sewage sludge application and natural processes—poses risks to soil fertility, food safety, and human health [82–86]. Organic farming mitigates metal accumulation by avoiding synthetic inputs and using amendments like compost, biochar, zeolites, and manure which enhance metal immobilization, improve soil structure, and promote microbial activity [87,88]. Crop selection and rotation with phytoremediation plants such as Brassica and sunflowers help manage contamination levels [89,90]. Microbial bioremediation with plant growth promoting rhizobacteria and mycorrhizae can further stabilize metals and reduce plant uptake [91].

However, these methods face challenges when applied to organic rice. Rice readily absorbs heavy metals such as Pb, As, and Cd, and crop rotation is rarely practised in rice cultivation, making phytoremediation or microbial bioremediation methods less applicable [90,92]. Silicon amendments offer promise by reducing heavy metal uptake and toxicity through forming silicate complexes, cell wall reinforcement, and altering metal bioavailability in the soil [93,94].

Mekong Delta context

ORF has been linked to benefits for soil health and quality in the MKD as well. The implementation of ORF in Ca Mau province in rice-shrimp agriculture has led to a rise in shrimp yields, underscoring its beneficial effects on both the environment and soil health [95]. In Dong Thap province, the utilisation of mechanical transplanting techniques and organic fertilisers has been found to enhance soil activation and structure [65,96] while organic farms in An Giang province had higher organic matter, more available nutrients and lower levels of heavy metals compared to traditional farms [97]. The latter is of particular importance in the MKD as geogenic arsenic is found pervasively in deep aquifers, with nearly 900 wells at depths of 200–500 m now contaminated while the usual methods of excavation and disposal of contaminated soil do not apply when contamination is continuously replenished from the ground water. The benefits of implementing ORF and organic fertiliser management on soil health and quality are reflected in section 5.1.7 and 5.1.9 of Vietnam's National Standard TCVN 11041-5:2018 on Organic agriculture - Part 5: Organic rice. It dictates that organic rice farmers comply with standards on heavy metals, pesticides and pH in soil, as well as taking measures to maintain soil biodiversity and avoid soil degradation.

### 3.1.3. Water Quality and Management

ORF shows promise as a sustainable approach to reducing water pollution, as it eliminates the use of synthetic pesticides and fertilisers and reduces the risk of nitrate pollution. Additionally, ORF reduces excess of nutrients such as phosphorus and potassium in soils, lowering the risk of ground and surface water pollution, and eutrophication of surface waters [98]. Long-term ORF practices are characterised by favourable water pH, electrical conductivity (EC), nitrate, residual sodium carbonate (RSC), and sodium absorption ratio (SAR) values compared to conventional systems (). Organic fields, with lower levels of nitrate, RSC, and SAR, consistently have better water quality in drinking sources such as wells compared to conventional fields, reducing the comparative risk of well water contamination (Sihi et al., 2020). For example, in Haryana, India, areas with 15 to 20 years of ORF practices implemented, saw a significant benefit to drinking water quality [99]. For irrigation purposes, well water quality parameters indicating salinity such as RSC and SAR follow a similar trend, with higher values in conventional agriculture indicating long-term soil risks due to salinisation [99].

The efficiency of water management is one of the aspects that have to be considered in benefit evaluation for ORF practices. In addition to overseeing the irrigation schedule of the rice field, water management encompasses the practices of evaporation control [50,100,101]. In particular the increase of SOM and its capability to increase the water retention of the soil benefits the water supply to the rice plants, particularly during drought conditions [100,101]. Therefore, increasing SOM in the field is a straightforward approach to saving or retaining water. In order to regulate evaporation, the implementation of mulching techniques might be also employed [102] as the application of mulch to the topsoil layer can effectively mitigate evaporation and enhance water infiltration rates. This approach can on the other hand increase some GHG emissions in semi-arid zones and needs particular approaches in order to reduce global warming potential in those regions. However, in humid regions such as Vietnam soil mulching minimises GHG emissions by significantly decreasing methane emissions [50].

In general, improving the soil hydrology via organic farming can lead to numerous advantages in water use efficiency by reducing agricultural water [50]. For example, in Sindangkerta Village, Indonesia, interviewed stakeholders reported that ORF required a lower volume of water and leads to a higher ability of soil to retain water compared to conventional methods (Johannes et al., 2019). Organic wastewater management approaches can also be used for cleaning drainage runoff and, as shown by Prikhodko et al. [103], wastewater successfully cleaned the drainage runoff from mechanical impurities, organic and biogenic elements if halophytes planted in phyto-sections located

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in the discharge channels of the rice irrigation system were introduced. By doing so, the irrigation rate was increased by 10%, the reclamation state of soils improved and the cost of rice production were reduced by 7% [103].

Mekong Delta Context

Organic rice farming techniques in different parts of Vietnam have enhanced water quality and improved management, including in the MKD [97]. In Bac Lieu Province, switching to organic rice farming (ORF) within a rice-shrimp cropping model—by avoiding chemical inputs—has improved water quality, enhanced environmental conditions for post-rice-harvest shrimp cultivation and crop diversification, and increased farmers' income by enabling wet-season rice production with freshwater irrigation and enabling shrimp cultivation during the dry season, when high water salinity prevents rice production in certain areas [64,104]. Similarly, farmers from an An Xuyen Commune in Ca Mau Province reported augmented shrimp yields complementing their organic rice cultivation due to improved water quality management, which resulted in both enhanced economic opportunities and water quality in the region [95]. The abundance of shrimp feed and healthy soil characteristics resulting from ORF comply with national regulations related to sustainable water management (QCVN 08-MT:2015/BTNMT on surface water quality and QCVN 09-MT:2015/BTNMT on groundwater quality.

#### 3.1.4. Human Health

While agrochemicals can enhance productivity, their overuse and improper application have been linked to acute and chronic health issues among farmers, workers, and consumers. Nitrates from fertilisers contribute to the formation of potentially carcinogenic nitrosamines [27,28,105]. Farmers are especially vulnerable to acute pesticide poisoning via skin contact, inhalation, or ingestion, while prolonged exposure has been associated with respiratory, dermatological, and neurological disorders. Pesticide residues may persist on harvested crops, entering the food chain and posing further risks, including cancer, hormonal disruption, and developmental issues [28,106,107].

In addition to reducing the health risks associated with rice grown in environments with higher chemical content, ORF has the potential for improving nutritional benefits for consumers of rice produced under organic standards. Studies assessing rice found that certain cultivars (e.g., IRGA 410) show higher yield, protein and lipid content in conventionally grown rice, while organic rice shows higher total carbohydrates, soluble protein, amylose content, and phenolic acids [108]. Especially phenolic compounds, as natural antioxidants, have gained importance for their health-promoting effects. According to Bergman and Pandhi [109], conventional farming increases rice grain length, kernel width, and their ratios. Organic farming, on the other hand, lowers quality by increasing the amylose content and decreasing crude protein content. Furthermore, Sihi et al. [110] found that the use of organic farming methods increased the levels of micronutrients (namely, iron, manganese, and zinc) in rice grains, something often overlooked in nutritional comparisons of CRF and ORF [111]. And although organically produced rice is less likely to contain residues of pesticides (e.g., organochlorine) compared to rice that is grown conventionally, some evidence suggests that organically grown rice can be more likely to be contaminated with mycotoxin-producing fungi and some mycotoxins [109].

Mekong Delta context

In the Mekong Delta as well, the use of NPK fertilisers and pesticides in rice farming poses significant human health risks. Due to the intensification of the agricultural sector in Vietnam over the last decades, ground- and drinking water were found to be polluted with pesticides at high levels [112–114]. Lack of personal protective equipment (PPE) and pesticide-related knowledge have been identified as major drivers of pesticide exposure for local farmers [115]. The persistent exposure of the wider population resulted in detectable pesticide residues in human blood, breast milk, and urine, which can yield to various negative health effects [116–119]. Excluding synthetic fertilisers, chemical pesticides, plant growth regulators as needed, to fulfil EU organic standards - or at least strictly limiting pesticide use as needed to fulfil US organic standards - will eliminate a number of well-established sources of health risks, primarily through reduced exposure to chemical pesticides.

Beyond direct exposure, pesticide packaging and waste handling also present environmental and health hazards. Improper disposal—such as leaving containers exposed to heat—can release airborne toxins that contaminate water sources and food supplies, causing digestive and respiratory illnesses [26,120]. Transitioning to ORF offers a pathway to reduce these risks by eliminating harmful chemical inputs, thereby improving health outcomes for local communities in the MKD.

#### 3.1.5. Biodiversity

Biodiversity plays a vital role in stabilizing and enhancing the resilience of ecosystems, including rice-based agroecosystems, against climate change [121–123]. However, conventional agriculture poses global threats to biodiversity through habitat loss and land use changes [124,125]. The persistence of native flora and fauna is strongly influenced by farming practices [126,127]. Arable plants, field birds, and insects—key to functions such as pollination and pest control—depend on agricultural habitats [127]. Paddy fields also function as anthropogenic wetlands, supporting aquatic and semi-aquatic species such as waterfowl, amphibians, and invertebrates [128–130]. Biodiversity patterns in paddies are shaped by proximity to non-paddy habitats, climate, soil conditions, and water availability [131]. Cocultures in rice fields can enhance both biodiversity and agroecosystem functioning [132]. Yet, rice-associated ecosystems face stressors from fungicides, invasive species, and infrastructural changes like concrete bank protection [133]. Warming may further amplify insecticide effects on aquatic insect communities [134].

Unsustainable farming and land conversion contribute to ecosystem degradation, affecting over 3 billion people globally [135]. Agricultural intensification has diminished the ecological value of rice fields [124]. CRF, which relies on synthetic inputs, compromises habitat quality through pollution, erosion, pesticide resistance, and biodiversity loss [136,137]. In contrast, ORF aims to reduce environmental harm and support biodiversity, nutrient cycling, and soil health [138–140]. By minimizing chemical inputs, ORF fosters biodiversity across taxa—including endangered plants, spiders, dragonflies, frogs, and soil microbes [124,141]. Both taxonomic and functional diversity improve under landscape heterogeneity and decline with pesticide use [142]. Waterbird richness increases with the proportion of organic fields, likely due to greater prey availability [124]. Enhanced soil microbial activity, nutrient cycling, and structure are linked to organic inputs and the presence of beneficial organisms like mycorrhizal fungi [47,69,70,79].

A comparative study found 58% of 474 cases showed higher species richness or abundance in ORF, with only 4% indicating negative effects; median plant species richness was 95% higher under organic management [127]. Gains were observed across birds (+35%), insects (+36%), and spiders (+55%). While ORF may slow biodiversity loss, its potential trade-offs—such as possible land expansion due to lower yields—must be considered holistically [124,143].

Mekong Delta context

Rice fields in Vietnam, including those in the Mekong Delta, provide habitat for a range of aquatic and terrestrial species [37]. These fields serve as temporary wetlands, providing breeding and feeding grounds for many species of birds, insects, amphibians, and fish [37,144]. However, intensified agricultural practices, characterised by increased use of agrochemicals, drainage changes and monoculture, disrupt ecological functions and can lead to pest outbreaks, soil degradation, reduced natural pest control services, and negatively impacts biodiversity. Agricultural land use changes in the MKD are evident in the shrinking of natural grasslands and melaleuca forests, which are converted for agricultural production. Even in protected areas or reserves, such as Lung Ngoc Hoang Nature Reserve in Hau Giang province, land is still being reclaimed for the purpose of farming, with over 800 households in the area producing rice and sugar cane [145]. Due to the interconnected nature of the landscapes and habitats in the MKD via the maze of waterways, the expansion and intensification of agricultural productions has negatively impacted biodiversity both within and outside of protected areas [145,146]. While there is an intuitive expectation that wider

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transition to ORF will have positive effects on biodiversity, more research is needed in the region [147].

**Table 1.** Diversity of benefits attributed to ORF from Vietnamese sources.

| Sources | Benefits reported in Vietnamese context | Benefit category |
|---|---|---|
| [65,96,97,148] | Improved soil health via organic farming techniques and organic fertilisers | *Environmental benefits* |
| [64,65,97,104,149,150] | Reduced pollution from chemical fertilisers, herbicides, and pesticides | |
| [97,148,151] | Enhanced biodiversity and encouragement of natural pest predators | |
| [64,66] | Improved crop resistance to diseases & pests | |
| [65,152] | Preservation of ecological condition | |
| [95,96] | Soil activation condition leading to favourable habitat for beneficial animals | |
| [65,68,148] | The production of nutritious organic goods for the consumption of consumers | *Health benefits* |
| [97,152] | Reduced health risks for farmers and consumers | |
| [63] | Strong plants with increased resilience to extreme events (e.g., storms) | *Agricultural and farming benefits* |
| [63,64,152] | Enhanced rice grain yield | |
| [63,64,66] | Reduction of pest & disease pressure on crops | |
| [65] | Enhancement of nutrient uptake efficiency in rice plants | |
| [66] | Improved livelihoods for farmers | *Social benefits* |

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| | |
|---|---|
| [148] | Provide farmers with support, training and resources to grow organic rice |
| [148,150] | Strengthening cooperatives and partnerships in agricultural production |
| [63,150,153] | Creating sustainable production chains |
| [65,148,150,152] | Increasing farmers' incomes |

3.1.6. Socio-Economic Opportunities and Challenges

Higher consumer prices for organic produce are probably the best-known economic characteristic of ORF, but by far not the only and not necessarily the most important one. Here we distinguish three kinds of economic effects: increased income, reduced expenditure and the effects on the farm workload, and in the social dimension the impact of reputation and urbanization. Besides these direct effects, there are also indirect economic co-benefits. Rice is the staple food of throughout South and East Asia – often in countries without a comprehensive system of free health care and sick leave payments. There ORF economic co-benefits include, for instance, less household spending on medical treatments, a health-induced higher working capability, or decreasing days of (usually uncompensated) sick leave. So far, such positive economic side effects are usually not accounted for in cost-benefit analyses of ORF. Basically, we can distinguish three kinds of income benefits: direct ones from the premium price paid for certified organic produce, indirect monetary co-benefits, and the economic losses avoided by ORF.

Increasing income

Increased public awareness of a healthy lifestyle and environmental sustainability has spurred an uptake in organic rice consumption, despite its higher market price, a phenomenon not constrained to high-income countries but shared by the consumer class in many low- and middle-income countries. Grimm et al. [154] tested consumers' willingness to pay for organic rice in urban and suburban Indonesia and found that respondents were willing to pay an average price premium of up to 20% compared to conventional rice. This is a key element of what prompts farmers to transition to ORF, as they hope to increase their business income [155]; our MKD interviews confirmed this. Such local demand is an essential requirement for increased adoption of ORF among smallholders, who typically have only limited access to export markets [154], unless they organize in cooperatives and these strike deals with larger rice trading companies. Although in the 2024 global rice price crisis, the sales of rice decreased for both conventional and organic rice, and the cost crises reduced the overall demand for premium products, in Vietnam traders like LotusRice continued to pay a premium of 40-50%. Nonetheless a significant number of farmers gave up organic practices, arguing that the high rice prices at the time allowed them to maintain their income without the organic-specific workload, although the income difference to conventional or safe rice (2-3% premium) would still have been significant. Apparently, for some farmers, the quality of life was more important than income maximization.

Organic rice production is usually assumed to result in inevitably lower yields and higher costs compared to conventional farming methods. However, there are diverging results regarding yield trends in the literature [44,156,157]. Eyhorn et al. [158] found that in Northern India, organic farmers achieved the same yields of cereals and pulses as conventional farmers, with considerably lower external inputs. Similarly, the average productivity of organic rice production in Nepal was found to be consistently higher than national average [159]. This aligns with earlier results from Java, which found that although the first year's harvest during the transition phase was significantly reduced, organic yields caught up with and surpassed those of conventional farming by the third year [160]. According to the authors, this was partly attributed to the lower pest infestation levels in organic as compared to conventional systems. Moreover, farmers in Vietnam and India using a mixed approach of both organic and inorganic fertilization benefited from applying organic fertilizers, as the amount of inorganic fertilizer required decreased [161,162].

Besides the health-related ORF co-benefits like less medical treatment expenditure, higher working capability, or decreasing days of sick leave, reduced pollution also generates indirect economic co-benefits. They occur when poultry and molluscs, indigestible or even dying in and around conventionally managed fields, become fit for consumption, or if honey bees survive and produce good honey. If collected and sold on the market, they provide monetary income – if used in the household diet, they provide a non-monetary economic benefit.

Enhanced resilience against climate change and intensifying disasters such as storms and salt water intrusions generates economic benefits from avoided losses. Hence, even additional monetary costs may appear justified as a kind of insurance premium, but this largely depends on the prevailing attitudes and the general level of knowledge. Benefits accrue not only to the farm itself, but also to the larger community, including e.g., groundwater and biodiversity protection, or social stability due to higher resilience. Finally, loss avoidance is the key motivation for going organic when ORF is applied out of necessity to counteract collapsing soil fertility and reduce the significant losses of yield experienced, as our interviewees in An Giang province reported. Then ORF helps avoiding further deterioration and revitalizing the soils to first stabilize and then increase harvests again.

Reducing expenditure

A study carried out in Lao PDR found that the most promising inputs and strategies available to optimize yields in organic rice production systems were identified to be (1) optimizing use of locally available nutrients, mostly from manure, crop residues and weed biomass, (2) N addition through green manure and legumes growing in rotation and (3) additions of P through guano or rock-phosphate [77]. This is similar, though not identical to the Indian experience of Singh et al. [47], who reported that different treatments comprising organic amendments such as Blue Green Algae (15kg/ha), Azolla (1 t/ha), Vermicompost and organic manure (5.0 t/ha) each applied alone or in combination, resulted in a significant enhancement in rice grain yield compared to rice crops that did not receive any fertilization. Moreover, rice grain yields was matching the yield achieved with the recommended dose of inorganic fertilizer application. In a study in Bangladesh, organic fertilizer users required 42% less farm capital for rice production, despite achieving 17% higher yields [163].

In Vietnam, on the one hand, organic agriculture tends to require less input of disease combating and pest regulating inputs, but on the other hand certified organic substitutes are not easily available. Organic fertilizers and pest regulation substances can be produced from different mixtures of local plants, farm residues and fish waste, but as they are usually not certified, they cannot be used in certified organic fields. What has become known as "safe rice" in the last two years (no management rules but zero pesticide residues in the final product required) can and does use such cheaper, locally produced, uncertified organic inputs alongside reduced volumes of seed (about 1/3 less, like in organic rice, as our interviews in Dong Thap and An Giang confirmed). This makes it competitive with organic produce despite a much lower market price premium. However, also the sourcing of uncertified organic inputs is not always easy – the optimal composition varies with location and resource availability, and traders we interviewed do not routinely offer it as the demand is too small to justify investments into setting up a production and supply network. On-farm production, while economically attractive, requires additional skills and working capacity. Hence, the cost and availability of organic fertilizers, specifically animal manure, could be a bottleneck for large-scale transition to organic [164].

Increased workload

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For the household economic balance, it is essential to consider not only market prices of sales and potential savings on inputs, plus salaries for remunerated farm workers, but the workload of (unpaid) family members as well.

Increasing workloads are frequent in organic agriculture. While in mountainous regions the natural slope limits the size of fields, and with it the level of mechanization, in flatland areas, typical for major deltas, fields tend to be large and the level of mechanization high. Direct seeding and fertilizing by drones (from a contractor, or for members from the cooperative) and with high-pressure "seed guns", and the use of big harvesters go together well with chemical inputs using the same equipment. While reducing insecticide spraying tasks, the transition to organic usually enhanced the demand for hand work in the fields, in some cases for transplanting instead of direct seeding[1], and in most cases including hand weeding, hand picking of snails (in particular GAS), and regular control of the fields regarding the occurrence of pests or diseases and checking the traps for rodents (rats). Hence, although organic farmers benefit from reduced input costs, they usually must contend with an increased workload. If not undertaken by unpaid family members or as mutual support on a community level, the salaries of farm workers have to be taken into account. However, in Vietnam they tend to be a minor factor in overall expenditure of a farm, according to An Giang farmers' estimates: even if all farm work would be done by paid workers, the total labour cost would be just 1/3 of the total profit a rice farm generates. is one solution.

Reputation and Migration

In many countries, and in Vietnam in particular, becoming a farm worker is one of the least appreciated job choices – whoever can, chooses a different career path. The attractiveness of farming as a profession for the younger generation is currently too low to guarantee a sustained production of healthy food and export crops. Farmers' children are leaving for better paid jobs in town or abroad, benefiting from the higher-level education they enjoyed as compared to their parents. Due to the resulting negative selection process, those left over are usually of low qualification, and have problems following the rules of land management and in particular the documentation requirements which are part of certified organic agriculture.

Besides the hard work, bad reputation is another reason. Reputation may increase when producing safe and health food, generating more reputation and more respect from society. Many parent farmers are confident that some of their children will return to take over the land after their careers, in particular if the farm is organic, offering a healthy life style and earning social respect from the community.

## 4. Discussion

Vietnam is one of the countries worldwide which is most susceptible to damages from the climate crisis [165]. However, storms, floods and rising sea water levels are but one of the sustainability challenges which together require an integrated compound response to safeguard a sustainable future for the MKD. For instance, overusing ground water and uncontrolled sand mining lead to falling ground water levels and accelerates salt water intrusion beyond the effects of climate change [166]. Besides high chemicals intensity, the dearth of nature protection plans and areas enhances biodiversity loss, with potentially significant impacts on rice production, organic or not. Upstream poldering and dams reduce sediment loads and hence the fertilisation effects of flooding (locally known as 'poor floods'), while high dykes enhance river bed erosion affecting agriculture and fisheries [167]. Lack of recognition, demographic change and urbanisation threaten to reduce the number of available farm labour. Infrastructure development, diets changing with increasing income and higher revenues from fruit, tree crops, orchards, sugarcane etc. increase the pressure for converting rice land to other uses.

ORF is an important tool mitigating a wide variety of these challenges, but no silver bullet solving all of them. It can build resilience to various threats and contribute both directly and indirectly to the reduction of vulnerability of local people, communities and ecosystems to different hazards faced in the MKD. For a future-proof MKD, however, ORF while being crucial has to be embedded into a larger framework of sustainability transition strategies.

### *4.1. Implications for Climate Change Adaptation and Mitigation in the MKD Context*

#### 4.1.1. Salinity Intrusion

Coastal soils and groundwater worldwide are increasingly affected by salinity intrusion, driven by climate change [168]. Rising sea levels are causing salinization of marshy and previously non-saline rice-growing soils [169] and aquifers. Salinity-tolerant rice varieties are thus critical for food security [169]. In Kerala's Kaippad integrated organic rice–aquaculture system, five traditional varieties—*Chovverian, Kuthiru, Kuttusan, Orkazhama, Orthadian*—and two novel varieties, *Ezhome-1* and *Ezhome-2*, demonstrate distinct salinity tolerance and contribute to ecosystem diversity [169–171]. Alongside plant breeding approaches, organic amendments—such as rice hull, straw, and sawdust—have proven effective in mitigating salinity stress, enhancing plant growth, yield, and soil reclamation [172].

In the Mekong River Delta (MKD), salinity intrusion, driven by climate change (altered precipitation, sea level rise, storm surges) and human activities (groundwater over-extraction, altered river flows), threatens water supplies and ecosystems [166]. Future projections indicate worsening conditions, making agricultural not only mitigation, but also adaptation urgent [173]. Evidence suggests organic rice farming (ORF) can improve groundwater quality and reduce salinity vulnerability compared to conventional systems [99], while mulching with organic materials helps retain soil moisture and lower surface salt concentrations [174]. Farmers in An Giang province report that organic fertilisers strengthen root systems and enhance resilience to weather extremes [63]. Consequently, ORF offers a viable climate adaptation strategy by increasing salinity resilience [175]. Socio-economic vulnerability may also decline as organic rice commands higher market prices and facilitates alternative livelihoods, such as shrimp farming, in increasingly saline areas [95].

#### 4.1.2. Flooding

Changes in flooding frequency and intensity are increasingly linked to climate-driven shifts in weather patterns, including heavier rainfall and rising sea levels [176]. Vietnam is particularly vulnerable due to its extensive low-lying delta regions [165]. The Mekong River Delta (MKD) experiences seasonal flooding that plays a vital role in delivering sediment and nutrients, supporting local agriculture and aquaculture [177]. However, extreme floods—such as the 2000 event causing 539 deaths and $210 million in damages [178]—can cause severe soil erosion and loss of agricultural inputs, disrupting farming cycles [179]. Climate-smart crops, selected for resilience to drought, heat, or flooding, are therefore increasingly valuable [179].

To mitigate flooding impacts, farmers and policymakers should focus on enhancing soil health, increasing water retention, and reducing surface runoff during intense precipitation [176]). ORF practices such as year-round soil cover and diverse crop rotations improve soil structure and humus, contributing to flood risk reduction [176]. Moreover, flood-tolerant rice cultivars offer adaptive solutions; in particular, organic varieties 'Ezhome-1' and 'Ezhome-4' demonstrate strong tolerance to prolonged flooding and tidal inundation in both saline and non-saline wetlands [170,180]. These varieties not only maintain high yields but also possess desirable grain quality traits, benefiting both farmers and consumers [170,180].

#### 4.1.3. Drought

Organic rice farming enhances soil and water resilience, crucial for mitigating drought [69,72]. Practices such as organic manure application improve soil fertility and nutrient uptake, supporting robust crop growth under water stress [73,181]. Higher SOM in ORF reduces soil density, thereby increasing water retention [182–184]. In contrast, chemical inputs tend to increase bulk density, decreasing water-holding capacity (WHC) and pore space [182]. Organic nutrition management, including manure and crop residues, enhances WHC and soil stability by promoting polysaccharide production, which fosters stable soil aggregates and improves moisture retention [72].

In the MKD, extreme droughts in 2016 and 2020 affected millions of hectares and caused economic losses of about $ 500 to $600 million USD [97,185]. Drought exacerbates salinity intrusion, creating multi-hazard challenges that reduce yields and threaten groundwater [186]. ORF improves soil porosity, permeability, and water retention, building drought resilience while ground cover—such as green manure, hedges, and flower strips—protects soil from erosion. Conservation tillage minimizes soil disturbance, preserving structure and enhancing infiltration and root growth. For instance, in the Philippines, crop residue recycling (3–4 t/ha) and animal manure application (1–2 t/ha) increased SOM, resulting in looser soils and deeper mud [187]. Similarly, soils under organic management generally show better granular structure and lower bulk density than conventionally managed soils [188]. In the MKD, organic farms exhibited higher nutrient absorption and less susceptibility to erosion compared to traditional farms [97]. These soil retention services contribute to reducing drought and erosion impacts, increasing resilience to salinity intrusion, and decreasing sedimentation downstream, benefiting reservoirs and coastal zones [189]. Widespread adoption of ORF could also mitigate pollution and eutrophication in surface and coastal waters, though effective solutions require landscape-level management beyond individual farms 189], but solutions have to be found on the landscape level, not by individual farms.

#### 4.1.4. Reducing GHG Emissions

In 2022, global greenhouse gas (GHG) emissions reached a record 53.8 GtCO2eq, with agriculture—including crop and livestock production—accounting for approximately 12% [190]. Rice cultivation is a major GHG emitter per unit area, largely due to fertiliser and water management practices that create conditions favouring anaerobe organic matter decomposition and excess nitrogen release, particularly methane [191]. Although emissions in rice production are partly inevitable, they can be mitigated. Conservation-based approaches such as sustainable intensification reduce soil disturbance and modify crop rotations, thereby lowering emissions [192]. Bacenetti et al. [193] found that in Italian organic systems, climate impacts were primarily driven by methane emissions from flooded fields (41%) and compost production (49%). Chen et al. [194] demonstrated through modelling and life-cycle assessments that integrated soil–crop system management can substantially reduce reactive nitrogen losses and GHG emissions. Organic fertilisers can produce up to five times lower GHG emissions than conventional fertilisers, especially when methane emissions from their production are minimised [195].

In Vietnam, agriculture accounts for 25–30% of total GHG emissions, half of which originate from rice production [36]. Rice cultivation contributes 75% of agricultural methane and 46% of nitrous oxide emissions [68]. Local authorities continue to prioritise economic growth and food security over emission reductions. Despite a recent central government initiative, mechanisms to encourage low-carbon rice production remain insufficient, and production costs under low-carbon agriculture are high [36]. New initiatives, such as the World Bank-funded “1 million hectare” project, promote reduced seeding and fertiliser use in the Mekong Delta to lower emissions and potentially enable carbon credit payments for farmers – a disputed option.

Organic agricultural practices can enhance climate resilience, particularly in vulnerable regions, by delivering multidimensional sustainability benefits (Table 2). Research with MKD communities and decision-makers shows that Sustainable Development Goal (SDG) targets on sustainable agriculture have strong positive linkages with other key sustainability goals [196]. Despite ORF’s potential to support climate resilience, further empirical research is needed on its effectiveness in reducing risks from floods, droughts, and salinity intrusion in Vietnam. Given the MKD’s vulnerability, assessing organic farming’s role within broader sustainable development strategies is urgent to improve resilience and support climate adaptation in this hotspot.

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**Table 2.** Benefits of ORF linked to climate resilience via increase (+) or reduction (-) of socio-ecological factors compared to CRF.

| | Benefit | Link to climate resilience | Challenge | Recommendation |
|---|---|---|---|---|
| **Weed & pest management** | *Chemical contamination (–)* | *Social and environmental vulnerability (-)* | *Farmer scepticism on effectiveness and resulting yield* | *Horizontal communication strategies, company compensation for yield deficits* |
| | *Number of species (+)* | *Human health (+)* | | |
| | *Cost-effectiveness (+)* | *Biodiversity support (+)* | | |
| **Soil Health** | *SOM / SOC (+)* | *Resilience to hazards (flood, drought, salinity intrusion, erosion) (+)* | *Managing cross-contamination* | *Integrated irrigation strategies at the farm and inter-provincial level* |
| | *Heavy metals (–)* | | | |
| | *Nutrient availability (+)* | *Human health (+)* | | |
| | *Chemical contamination (-)* | *Biodiversity support (+)* | | |
| **Water Quality** | *Chemical contamination (-)* | *Resilience to hazards (flood, drought, salinity intrusion) (+)* | *Managing chemical flows and extreme flood events* | *Identify point sources, change pollution management approaches* |
| | *Water-use efficiency (+)* | *Human health (+)* | | |
| | *Water retention (+)* | *Biodiversity support (+)* | | |
| **Economic gain** | *Input costs (-)* | *Socio-economic vulnerability (-)* | *Certification, market prices and labour costs* | *Enhance market connections, develop local production of farm inputs* |
| | *Profit potential (+)* | | | |

*4.2. Challenges for Organic Transition*

Despite the wide-ranging potential benefits ORF can provide for climate change adaptation the increasing integration of organic agriculture targets in policy, the speed of the transition has been hindered by ongoing challenges which must be comprehensively addressed. One of the reasons appears to be that the most effective incentive for transition is via market prices, where a higher market price for organic rice can be a strong (but not always sufficient) motivator for transition, while a nominally different price can lead to a reluctance for transition [197,198]. In many cases the social and environmental benefits are given lower priority in farmers' decision making [199]. Key challenges emerging from the literature and our observations are summarised below.

#### 4.2.1. Managing Water and Soil Contamination

Over recent decades, concerns have grown globally about the impacts of agricultural activities on water and soil pollution due to cascading effects on environmental and human health. In Bangladesh, for example, farmers and consumers recognize the risks of chemical inputs but remain largely unaware of organic rice farming [200]. In rice paddy systems, water quality issues arise from both contaminated irrigation inflows and nutrient-laden outflows [201]. While the environmental impacts of CRF like water use inefficiencies, flooding, and nutrient leaching, and aerobic methane generation are well-documented [202–204], research on ORF—particularly during the transition phase—remains limited [149,205,206]. Transitions in the MKD have at times failed due to inadequate monitoring of residual agrochemicals and the incidental import of pollutants via irrigation before certification [149].

Furthermore, while pesticide pollution in CRF is widely acknowledged, its role in hindering organic transition via contaminant residues in irrigation and floodwaters remains underexplored. Agrochemicals from adjacent CRF areas can contaminate transitioning farms through shared irrigation networks. Floodwaters during the rainy season also carry pollutants from distant farms, villages, and upstream cultivation areas [202]. Despite this, the influence of regional crop landscapes on agrochemical transfer is poorly studied, partly due to limited high-resolution pesticide and crop data [207].

Land use has been shown to significantly influence water quality [208]. In the U.S. and Thailand, studies have linked pesticide use and human exposure to specific crop types, including rice, via land use classifications [209,210], indicating the need for landscape-scale solutions. In the MKD, rice—especially in triple-cropped areas—is the primary pesticide-exposed crop. Authorities also identify aquaculture and livestock as major pollution sources due to the discharge of pesticides, antibiotics, and hormones [32,204]. Dyke systems are additional hotspots for agrochemical accumulation [211,212].

Pesticide use is typically higher on large, intensively managed farms and is linked to reduced crop diversity, decreased natural pest control, the removal of non-crop habitat, though this varies by crop type [207,213]. Past use can play a role when accumulated pesticides contaminate the breeding or foraging areas of biocontrol species. However, no study has thoroughly examined the link between specific crops in the MKD (e.g., orchards, tree crops, sugarcane) and pesticide-related water pollution. This gap, likely due to data limitations and a focus on spatial intensity over crop type, complicates the identification of CRF areas suitable for conversion. The risk is significant: certification for organic production may be denied if chemical residues are detected in soil or crops.

#### 4.2.2. Certification Processes, Costs and Markets

Farmers must undergo a minimum two-year transition period before obtaining organic certification, during which they are required to follow organic practices but cannot market their products as organic. This period poses economic risks, as yields may be lower while soil benefits remain limited, and prices for "pre-organic" rice remain similar to those of conventional rice [76]. Certification involves following stringent rules covering conversion, seed use, fertilisation, pest and disease management, crop rotation, labelling, and post-harvest handling [214]. The process is often costly and time-consuming, particularly for smallholders, due to high fees and labour-intensive documentation, and has to be regularly repeated to maintain the validity of the certificate [199,215]. In Nepal, additional barriers include limited organic markets, high input costs, lack of training, and

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insufficient government support [215]. In Iran, inspection costs and the absence of branding efforts hinder organic adoption [216]. These challenges underscore the need for support from partners willing to share investment risks and promote branding and marketing [217].

Perceptions of higher labour requirements also deter adoption, though impacts vary by task. In the Philippines, family labour was essential during the transition, especially for composting, hand-weeding, and pest control, while reduced pesticide use and easier land preparation offset some burdens [187]. Similarly, in Bangladesh, organic fertiliser use required 12% less labour despite achieving 17% higher yields [163]. Nonetheless, labour demands and the limitations of smallholder capacity remain significant barriers to scaling organic rice production [218].

#### 4.2.3. Knowledge Management—Farmer Education and Training

Organic farming is only economically viable when production factors are efficiently managed; efficiency—defined as the optimal use of inputs for maximum output at minimal cost—directly influences yields and income. Beyond physical inputs, knowledge and skills are essential. As Pawitri et al. [155] observed in Indonesia, failure to recognize their importance limits productivity. However, awareness alone is insufficient. Devi et al. [199] found that while Indonesian farmers understood organic principles, they often failed to meet the procedural standards set by the Indonesian National Standard (SNI) and international bodies like Organics International (IFOAM) the United States Department of Agriculture (USDA). This reflects a broader knowledge–action gap, where individuals do not always act on what they know to be beneficial [219]. Lal et al. [220] similarly reported that only half of the perceived barriers to organic transition in India were linked to knowledge, with other challenges including complexity of application, poor-quality inputs, and limited guidance.

Training has been identified as a key factor in organic adoption, particularly within sustainable agricultural networks. In Northern Italy, a participatory project showed that enhancing farmer skills led to improved yields and reduced variability, emphasizing that successful organic management depends on applying agroecological principles flexibly in response to local conditions [221]. For risk-averse, rice-dependent smallholders, lack of knowledge can be a significant barrier. However, strong social networks and information exchange—such as in Vietnam and Taiwan—can foster trust and investment in organic practices through peer influence and “neighbourhood effects” [161,222,223]. Nonetheless, informal exchanges must be supported by formal interventions, including training, education, and comparative studies in cultivation and marketing [224].

## 5. Recommendations for Maximizing Diverse ORF Benefits in the MKD Context

### *5.1. Focus on Areas with Poor Soil Condition and High Risk of Climate Impacts*

While organic transition often requires areas with lower residual chemical pollution, in Vietnam it is usually recommended for regions with good soil qualities. However, regions of poorer soil quality can also benefit from ORF, maybe even more, as international examples illustrate. Successful organic conversions frequently occur in less-favoured agricultural areas with smaller fields and limited mechanisation, where yields have increased and stabilized [225]. Farmers in low-potential areas face lower opportunity costs and may be more willing to adopt organic methods [223]. Government institutes in several countries therefore recommend focusing organic agriculture on poor soil areas while seeking alternative strategies to reduce environmental impacts for high-input agriculture in fertile areas [111]. Declining soil quality under conventional farming may further motivate adoption of organic practices.

Given ORF’s potential to enhance resilience to climate hazards like salinity, storms, and drought, mitigate biodiversity loss, and improve the social status of farmers as well as their income, expansion plans should incorporate broad assessments and climate modelling to prioritize benefits. A landscape-level, integrated approach is essential, combining farm-level organic practices that reduce chemical loads and promote biodiversity with inter-provincial sustainable water management. This approach should leverage existing irrigation infrastructure to minimize chemical runoff, where possible restore sediment flow, and improve groundwater recharge.

*5.2. Further Research on Chemical Flows and the Effectiveness of Different Irrigation Approaches*

Given the Mekong Delta's complex hydrology and intensive agriculture, landscape-level planning and transformation are essential to avoid cross-contamination. . Additional data on the sources and fate of chemical contaminants across the MKD are critical for managing chemical residues in irrigation and floodwaters during organic transition and ongoing organic production. Existing irrigation infrastructure may inadequately control chemical flows, especially for farmers who cannot afford or must share facilities with conventional producers. Therefore, diverse irrigation strategies tailored to maintaining organic standards should be explored to effectively manage chemical contamination.

*5.3. Context-Specific Policy*

It is essential to recognize that 1) ORF is not necessarily beneficial in comparison to CRF in all contexts and for all criteria, and 2) the drivers that reduce its ability to deliver benefits are multiple. Prescribing market-driven farming notions in different cultural and ecological settings can lead to contradictions, and certification requirements, resource constraints, and labour demands can exclude some farmers [226]. Therefore, the analysis of organic farming as a rural development strategy should consider not only economic returns but also the broader socio-political context and the influence of development agencies on poverty reduction potential [226]. Ideology and practices play a significant role in this context, and recommendations should be sensitive to local conditions [227]. The importance of environmental benefits for health and well-being of delta-dwellers should also not be understated and accounted for in policy. While this often includes non-monetary benefits such as increases in biodiversity, the indirect economic benefits through increased opportunity for income diversification and crop resilience should be considered in long-term policy approaches.

*5.4. Develop Targeted Organic Policy Approaches and Knowledge Transfer Systems*

A lack of clear organic-specific policies (distinguished from 'safe', 'clean' and 'ecological' rice, for instance) contributes to mixed and not necessarily coherent approaches to ORF in the MKD. Limited mandates and staff shortages in local extension workers' offices shift the role of monitoring and evaluating protocols to companies. In particular, the system of training and information for farmers through agricultural extension workers can vary in effectiveness depending on how they themselves are trained and how far they are entitled to engage with individual farmers.

Without a standardised oversight of both ORF and CRF farms there is scope for approaches that could compromise the ability to control chemical flows and realise diverse benefits of ORF. Direct exchange between farmers from different villages and provinces is a promising way to facilitate learning and problem solving for ORF, and should be seen as a way to promote success stories in organic farming while addressing reasons for scepticism in farmers who have little insight to the reality of organic farming. Administrators at the district and higher levels could provide platforms for farmers to share experience amongst each other, and to raise concerns and needs with government officials.

## 6. Conclusions

Our literature compilation highlights the significant benefits and challenges of organic rice farming (ORF) compared to conventional methods, focusing on the Mekong Delta (MKD), a vital yet climate-vulnerable rice-producing region. Evidence shows ORF delivers economic gains, improved soil and water quality, enhanced biodiversity, and better health outcomes for farmers and communities. These benefits also bolster climate resilience by improving soil properties and mitigating impacts from floods, drought, and salinity intrusion.

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However, ORF's success is highly context-dependent, requiring further research on site-specific conditions and transition strategies to inform effective policies. Challenges such as cross-contamination from nearby conventional farms, limited market access, insufficient government support, frequent policy changes and high input costs must be addressed to unlock ORF's full potential.

The MKD faces compounded threats from extreme weather, sea-level rise, and altered hydrology, biodiversity loss, demography and urbanisation, demanding integrated sustainability including climate adaptation strategies. Organic farming, combined with smart technologies (e.g., the wide-spread use of drones for seeding and fertilising) , offers nature-based solutions but must be embedded within adaptive governance frameworks at both landscape and farm scales. Only then can agricultural sustainability be safeguarded amid ongoing and future environmental pressures.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| MKD | Mekong Delta |
| ORF | Organic rice farming |
| CRF | Conventional rice farming |
| GHG emissions | Greenhouse gas emissions |
| SOM | Soil organic matter |
| SOC | Soil organic carbon |
| RSC | Residual sodium carbonate |
| Pb, As, Cd, Zn, Cu | Lead, arsenic, cadmium, zinc, copper |
| NPK | Nitrogen, phosphorus, kalium |

## Note

1. However, while heavy work, transplanting has its benefits: it allows for better control of the distance between rice plants, which can reduce the vulnerability to disease outbreaks and pest infestation. It also reduces the damages from golden Apple Snails (GAS) as the time between rice seedlings being put in the field and becoming indigestible to GAS due to silicon incorporation of rice plants is shorter.

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