Agricultural and Food Economics

RESEARCH Open Access

Exploring willingness-to-pay for 'malaria-free' rice among rural consumers in Rwanda: examining the potential for a local voluntary standard

Alexis Rulisa[1*], Luuk van Kempen[1] and Dirk-Jan Koch[1]

*Correspondence:
alexis.rulisa@ru.nl

[1] Department of Cultural Anthropology and Development Studies, and Radboud Social Cultural Research, Radboud University, 6525 XZ Nijmegen, The Netherlands

Abstract

Rice cultivation in Sub-Saharan Africa produces a negative externality in the form of higher malaria risk. Larval source management, such as the application of bio-larvicides in rice fields, is available to mitigate the problem. However, the cost of larvicide and the corresponding spraying campaigns is such that rice farmers are unable to carry all of the financial burden themselves. This study explores in a rice-growing area of Rwanda whether, and to what extent, local consumers are willing to share this burden through their consumption choices. In a non-incentivized format, we elicit willingness-to-pay from 290 respondents for locally produced rice that is cultivated in either sprayed or non-sprayed fields. Price premium estimates are extracted to discuss the prospects of a voluntary sustainability standard for 'malaria-free' rice. We observe robust support among local consumers to re-align food production and public health through the marketplace. The results thus warrant a critical reflection on the assumption in the ethical consumption literature that consumers in the Global South, especially those on low incomes in rural areas, cannot play their part.

Keywords: Rice consumption, Ethical premium, Willingness-to-pay, Malaria vector control, Voluntary sustainability standard, Rwanda

Introduction

While beans have traditionally been the main staple food of Rwanda, as witnessed by the world's highest per capita bean consumption (CGIAR, 2015), the food crop that currently takes the largest share from the food budget of Rwandan households is rice (Ghins and Pauw 2018). The Ministry of Agriculture predicts rice consumption to jump from 11.4 kg per person per year in 2018 to 14.4 and 17.4 kg by 2024 and 2030, respectively (MINAGRI 2021). Given this projected increase in demand, exacerbated by strong population growth at 2.5% per year, and the government's aim to increase the rice self-sufficiency ratio from 47.7% (2018) to 90% in 2030, an ambitious expansion of the country's rice cultivation area is foreseen alongside yield improvement measures.

This prospect of expanding rice fields is problematic from a public health perspective, however. Rice cultivation is often linked to enhanced malaria risk, as rice paddies constitute an attractive breeding habitat for *Anopheles* mosquitoes. A systematic review of studies analysing this link across Sub-Saharan Africa corroborates that malaria incidence tends to be higher in rice-growing villages compared to communities without rice cultivation, at least when focussing on studies conducted since 2013 (Chan et al. 2022). A study by Mangani et al. (2022) in Malawi evidences more specifically how malaria incidence varies with proximity to a rice cultivation site. Households residing within a 3 km perimeter around a rice irrigation scheme in central Malawi had a 41% higher probability of malaria infection than those living at 3–6 km distance. The authors corroborate that this infection rate was mediated by a higher density of *Anopheline* mosquitoes. Our own work in Ruhuha sub-district in south-eastern Rwanda, i.e., the focus area of this paper, established that rice-growing households reported more fever, as a proxy for malaria, than those not involved in rice cultivation (Rulisa et al. 2022). This aligns with existing evidence that rice cultivation entails a negative externality in terms of disease burden, undermining recent progress in the country's fight against malaria. Karema et al. (2020) point out that Rwanda's acclaimed success in malaria control, which they attribute to 'high coverage of effective malaria interventions and massive investment in health systems strengthening' (p. 10), remains vulnerable to setbacks as a result of changing interactions between humans and vectors. The expansion of wet agriculture may qualify as such and thereby presents a fresh policy challenge. Malaria exposure is not (yet) on the radar of Rwanda's agricultural policymakers; insofar national agricultural policies focus on health; the main focus is on nutrition.

A solution to minimize the adverse impact from rice on malaria is to spray rice paddies with biological larvicide, most commonly *Bacillus thuringiensis* var. *israelensis* (*Bti*), which has proven effective in reducing the *Anopheles* population in sub-Sahara African settings, albeit to varying degrees depending on context, quality of application, and ancillary malaria control measures (Derua et al. 2019). However, sustaining a larviciding campaign is costly. For reference, an elaborate costing exercise of community-based larval source management using *Bti* in a rural district in Malawi amounted to implementation costs of US$20.46 (2017 dollars) per person per annum, which increased to US$25.06 if the opportunity costs of voluntarily dedicated time by community members were added (Phiri et al. 2021). Within our study area in Rwanda, we have assessed (ex-ante) willingness-to-pay among members of rice farmer cooperatives to co-finance a larviciding campaign in their paddies and found positive (non-zero) but modest contributions in the range of 15–25% of full cost coverage (Rulisa et al. 2021). After carrying out a 6-month larviciding pilot with three rice cooperatives in Ruhuha in 2015, this level of willingness-to-pay was broadly maintained in two out of three cooperatives ex-post, i.e., when revisiting these farmer groups 18 months after the pilot (early 2017). When discussing financial sustainability of larviciding during focus group conversations with the rice farmers at the time, several participants pointed to the financial co-responsibility of consumers in keeping rice production 'malaria-free'. The suggestion was made to raise the market price of rice, allowing for a partial pass-through of the extra cost of larviciding to local consumers. To what extent the local customer base for rice in Ruhuha, a

distinctly rural area, is willing to offer such financial support is the main question of this paper.

Involvement of consumers in tackling negative externalities of production is well-established within the concept of 'ethical' or 'responsible' consumption, which Oh and Yoon (2014) define as "conscientious consumption that takes into account health, society, and natural environment based on personal and moral beliefs". It concerns voluntary acts of consumption favouring products that avoid or minimize negative impacts on society. However, this idea is strongly centred around consumers in the Global North (Gregson and Ferdous 2015). Ethical responsibilities are projected on Northern consumers "by virtue of their position at the apex of global value chains" (ibid., 244), while the Global South is primarily envisaged as a site of (export) production rather than one of consumption. Gregson and Ferdous (2015) argue that, by implication, it is assumed that "ethical consumption and ethical consumers are absent from the South" (ibid., 245).

The authors dispute the latter suggestion in reference to the strong emergence of middle-class consumers in the Global South. In our case, we also question the implicit assumption that ethical considerations are out of league for consumers in the Global South, but simultaneously put Gregson and Ferdous' assumption that consumer responsibility is "inevitably middle class" (ibid., p. 252) to the test. We present rural consumers in Ruhuha, who do not fit the 'middle class' category, with a hypothetical choice that features a package of rice with a smaller public health footprint than the mainstream option, and manipulate prices to detect any premium for the more socially responsible alternative. Note that the results may not only serve to assess the potential for voluntary (private) initiatives to push malaria-free rice, but might also inform policymakers on the degree of popular support for 'command and control' policies, such as a consumption tax on non-sprayed rice.

A distinctive aspect of our study is the focus on ethical food consumption involving a health externality, as the bulk of ethical initiatives in agri-food value chains address consumer concerns regarding socio-economic or environmental impacts from agriculture or agro-processing. Securing a 'living wage' for agricultural workers, abolishing child and bonded labour, and reducing deforestation are prominent examples. Therefore, we first scope a set of studies that relate agriculture in the Global South to negative health impacts and review the proposed policy instruments targeted at consumers to mitigate these. Then we position our willingness-to-pay (WTP) study vis-à-vis the (limited) body of evidence on WTP for ethical attributes of rice in the Global South. The Methods and Data section elaborates on the study setting, explains the consumer choice format used for WTP elicitation, and introduces the sample. In the Results section, the WTP outcomes are analysed and its main drivers identified, which feeds into policy-oriented reflections in the Discussion section. Finally, we briefly revisit the assumption that ethical consumerism is the prerogative of affluent consumers in the Conclusions section.

Literature review

Leveraging consumer instruments to address agro-based health externalities

The negative impact on public health from rice cultivation presents a classic market failure, as the societal cost of increased exposure to malaria is not factored into the market price of rice. The textbook policy response to such a negative externality would be a

Pigouvian tax to re-align private and social cost (Mulligan 2023). A consumption tax on rice, or a production tax levied on rice farmers, could be employed to raise the market price to its social optimum. Popular support for such interventions that localize societal costs depends strongly on the degree to which the negative externality is acknowledged and understood by the consuming public (Fitzgerald et al. 2016).

Apart from such a corrective tax-based approach, however, externalities that arise in agricultural commodity sectors can also be targeted by voluntary sustainability standards (VSS). Rather than relying on the government's tax powers, VSS are voluntarily taken up by the private sector itself to address societal concerns. Design and/or implementation can be organized in collaboration with the civil society groups that advocated for change, and may involve (inter)governmental institutions as well. UNCTAD (2020) defines VSS as "private standards that address not only product quality and attributes, but also production and processing methods". As such, these are "standards that require products to meet specific economic, social or environmental sustainability metrics", which may include "respect for basic human rights, worker health and safety, the environmental impact of production, community relations, land use planning and others" (p. 2). Standards related to worker rights (fair trade certification) or environmental impacts (eco-labels) have gained most traction (Marx et al. 2022). Hence, the focus of VSS is on the (non-tangible) ethical attributes of agricultural commodities rather than, or alongside, its intrinsic or extrinsic quality attributes. Note that the VSS approach re-interprets the market failure as an information asymmetry between producers and consumers, where the latter cannot distinguish between products that were produced sustainably or not (UNCTAD 2020). This asymmetry can be redressed if a VSS is put in place, communicated to consumers through a recognisable seal on-pack and backed up by a credible verification process.

No systematic review is available to offer guidance on whether a tax-based or VSS-oriented solution is more feasible or effective in addressing agriculture-driven negative health externalities. In fact, adverse health effects from food production in the Global South have only recently gained more structural attention. Rohr et al. (2019) provide a comprehensive review of the links between food production and communicable disease risk from a global perspective. Such a focussed review could not be retrieved for the relation between food production and non-communicable disease risk, but Pullar et al. (2018) indirectly produce one. They screen development interventions in low and lower-middle income countries, concentrated in the agricultural domain, for impacts on non-communicable disease. First we extract singular cases of negative health externalities from both reviews and, subsequently, scope the literature to purposively retrieve studies related to each of these cases. As entry points we performed a literature search on the combination of the agricultural activity producing the externality, often a specific commodity, and the corresponding health risk. The studies retrieved were then filtered on containing either an evaluation of, or proposition for, a consumer price instrument. Full texts were screened by using 'consumer', 'consumption', 'price', 'policy', 'certification' and 'tax' as individual search terms. This scoping exercise resulted in a set of six qualifying studies. Table 1 profiles these cases according to five features that define the rice-malaria case in Ruhuha and are listed in the first column. The remaining columns explore the degree to which each of the cases from the literature (*a* to *f*) share these features. The

Table 1 Consumer price instruments to mitigate negative agriculture-driven health externalities in the Global South: own-case comparison

Ruhuha case, Rwanda	**(*a*) Chaves et al. (2020)**	**(*b*) Okpiaifo et al. (2020)**	**(*c*) Runkle et al. (2021)**	**(*d*) Larnder-Besner et al. (2020)**	**(*e*) Hangoma & Surgey (2019)**	**(*f*) Estrada (2018)**
Health externality .. concerns mosquito-borne infectious disease (malaria)	●	○ NCD[#] [occupational hazards]	○ NCD [arsenic poisoning]	◑ CD[#] [zoonotic pandemic risk]	○ NCD [obesity-linked diseases]	○ NCD [lifestyle diseases]
.. stems from wet agriculture (rice cultivation)	◑ Crop agriculture [e.g. cocoa, coffee]	●	●	○ Livestock production [meat]	◑ Crop agriculture [sugarcane]	◑ Crop agriculture [tobacco]
.. emerges exclusively in production stage	●	● [e.g. agro-chemical exposure]	◑ Production & consumption [toxic metalloids]	◑ Entire value chain	○ Consumption stage [intake of sugary foods]	○ Consumption stage [smoking]
.. impacts producers & production area residents	●	◑ Producers only	○ Consumers only	◑ All	○ Consumers only	○ Consumers & co-residents [second-hand exposure]
.. is localized (spatial proximity of producers, consumers & affected residents)	○ International [Southern farmers v. consumers in North]	◑ National [Nigeria; rural farmers v. urban consumers]	◑ National & regional [South(east) Asia]	◑ Local & global [meat product exports]	◑ National [Zambia]	◑ National [Philippines]
(Proposed) consumer price instrument	VSS* [crop-specific]	VSS [crop-specific]	VSS [crop-specific]	Tax[‡] [global]	Excise tax [national]	Excise tax [national]

Colour-coding of dots indicate degree of similarity with our case; black dot = strong similarity or shared feature; half black/half white dot = medium similarity; white dot = weak or no similarity

#(N)CD = (Non-) Communicable Disease

*VSS = Voluntary Sustainability Standard

‡ Tax is proposed to be levied at country level based on a nation's global consumption share; governments may choose to pass the cost on to local consumers

degree of similarity is primarily used to guide the framing of the WTP elicitation (tax or VSS), but Table 1 simultaneously serves as a preliminary attempt to arrive at a typology of agriculture-driven health externalities in the Global South.

The scoping exercise failed to encounter a case on the rice-malaria nexus itself. Case (*a*) deals with increased malaria exposure from cash crop cultivation due to land conversion, although the underlying channel is different. Instead of rice cultivation, the driver is deforestation linked to plantation agriculture (see Burkett-Cadena and Vittor (2018) for a review on this link). Only one other case (*d*) is concerned with infectious disease risk from agricultural activity, but of a zoonotic rather than parasitic nature. The remaining cases concern non-communicable health conditions, either related to rice specifically (*b* and *c*) or another crop (*e* and *f*).

More interestingly from a typological point of view is the variation in locus of the externality (see fourth row). Where malaria is concerned, it emerges exclusively in the production stage. The NCD equivalent of such a production-only externality is observed in case (*b*), which highlights occupational health hazards for rice farmers in Nigeria, in particular agrochemical exposure. By contrast, a health externality may also be contingent on the act of consumption, even if the root cause of the problem lies in the cultivation stage. This is the case of arsenic poisoning risk when eating polluted rice (*c*). In other cases the health externality is unrelated to the production process altogether, and exclusively stems from (over)consuming a specific agricultural output, such as sugar or tobacco (*e* and *f*). In special instances, the externality is tied to intermediate value chain stages. An example is presented by case (*d*), where the trading stage is considered the most risky in terms of spreading zoonotic disease.

This locus of the externality to some extent predicts the incidence of health impacts (fifth row). Producers (consumers) are the main at-risk category if the externality is tied to the act of production (consumption). Communicable diseases like malaria, however, travel beyond the actors involved in the value chain of an agricultural commodity and potentially affect all residents within the wider cultivation area. Such amplification of impact beyond chain actors is less likely in the case of NCDs, or if the externality is tied to consumption, but the second-hand smoke exposure that tobacco users inflict on non-smokers (case *f*) presents a counterexample. This draws attention to the spatial proximity of different stakeholders in a case (sixth row). Our Ruhuha case is unique in this respect, as producers, consumers and affected others co-reside in a relatively small area. In fact, the producer and consumer categories partly overlap. This contrasts with cases where consumers are physically distant from cultivation sites, such as in the case of export crops that cater for international consumers (*a*). Even if consumption is domestic, urban consumers can be physically, but also psychologically, quite distant from farming communities. Metropolitan rice consumers in Lagos, Nigeria, are a case in point (*b*). It is different in the case of cocoa and coffee (*a*), where Northern consumers are located far from the cultivation sites in the Global South and thus effectively shielded from negative health impacts.

The selected studies are equally split where it concerns the preferred consumer price instrument to deal with the health externality at hand. Three cases put forward a voluntary sustainability standard (*a*, *b*, and *c*), while the remaining cases evaluate a tax-based solution (*d*, *e*, and *f*). In the latter group two cases evaluate an excise tax labelled as 'sin tax', connected to the harm that consumption inflicts (*e* and *f*). This fits a wider trend of 'sin taxes' no longer being confined to affluent Northern consumers, but proliferating in low- and middle-income countries as well (Elliott et al. 2022). Such health-minded policies are enacted in spite of the economic importance of the impacted agricultural sectors, such as sugarcane and tobacco cultivation. Yet, such a sharp trade-off between consumer and producer interests does not apply to rice. Rather than qualifying as a temptation good for which demand needs to be curbed, higher consumption levels of rice are desired in the Rwandan context to enhance dietary diversity. Signalling otherwise in the form of taxation does not seem a recommendable policy, therefore. Also, the 'sin tax' cases share relatively few characteristics with the rice-malaria case, as per the overview in Table 1.

The two most similar cases (*a* and *b*), which share at least two features, both opt for a voluntary sustainability standard, offering consumers the possibility to weigh up the competing objectives of dietary diversity versus malaria risk individually. The Nigerian case (*b*) explicitly refers to an existing VSS in the rice sector, launched as a global initiative by the Sustainable Rice Platform (SRP) in 2015 under the auspices of UNEP and the International Rice Research Institute (IRRI). The standard's latest update (SRP 2020) has specific attention for producer health (occupational hazards), but does not mention the risk of creating a habitat for malaria mosquitoes, nor makes any other link to communicable disease risk. Hence, we consider a VSS to be the most appropriate policy instrument to explore in our case, but opportunities to buy in on an existing global standard seem absent.

Evidence on willingness to pay for ethical attributes of rice

A VSS likely involves a mark-up on price in compensation for compliance with the standard. However, Marx et al. (2022) point out that "price premiums are not guaranteed and depend on consumers' willingness to pay" (p. 24). This condition seems particularly critical in Rwanda's rural context, where poverty and food insecurity are widespread. Therefore, we test the following hypothesis: A VSS can be leveraged as effective instrument to internalize the public health cost of malaria-inducing rice cultivation among rural consumers in Rwanda. This implies a substantial share of local consumers committing to non-zero premium payment.

Unfortunately, studies on WTP for extrinsic health attributes of rice have not been encountered in the context of low- or middle-income countries. It is nonetheless helpful to review WTP studies conducted in the Global South on other extrinsic attributes of rice, especially environmental friendliness, if only to mark out how the current WTP study supplements the existing body of evidence. This evidence is highly concentrated in middle-income Asian countries and tends to be biased towards urban, well-educated consumers, as illustrated below.

Zhou et al. (2017) carry out a discrete choice experiment among Chinese consumers for rice with and without an eco-label. The sample is recruited from several cities in rice-cultivating provinces and is reportedly younger, higher-educated and wealthier than the average Chinese consumer. The study finds average WTP to be in the range of 35–45% for eco-labelled rice, driven by consumers with high levels of environmental awareness, high family income, and strong educational qualifications. A more representative consumer sample for China features in a study by Wang and Gao (2017). Their online survey explores WTP for rice produced in a traditional rice-fish system rather than under monoculture, where the former is the environmentally sustainable option. It uses a specific contingent valuation technique where respondents pick out their maximally acceptable price from an ordered list of threshold values (payment card approach). On average a 41% premium was recorded for the more sustainable option. Similar to Zhou et al. (2017), premium payment is concentrated among consumers with relatively high levels of household income and strong intrinsic motivation with respect to ecological values. Unfortunately, respondents were apparently not cued on the potential health benefit that an integrated rice-fish system embodies. As acknowledged by the authors, the presence

of larvivorous fish inhibits the growth of mosquitoes and other insects in the rice paddies, and thereby reduces vector-borne disease risk.

My et al. (2018) link WTP more directly to VSS implementation in the Vietnamese rice sector. The VSS in question is VietGap, a national multi-sector sustainability standard. They invited a sample of urban consumers to participate in incentive-compatible WTP bidding for rice with and without the VietGap logo. The bidding applies the BDM mechanism, which is similar to a second-price auction, but prices are generated by a random device rather than shaped by competing buyers (Flynn et al. 2016). The study reveals an average price premium in the range of 9–33% for VietGap-certified rice, depending on the amount of information provided to participants on VietGap's criteria and traceability system. Concerns about the environment as well as food safety proved significant predictors in explaining whether certified rice commanded a premium. In line with the results obtained on Chinese consumers, premium payers were concentrated in the upper-middle income segment. Finally, Connor et al. (2022) recruited a sample of Vietnamese city dwellers to assess WTP for rice certified according to the SRP-standard introduced before. Unlike My et al. (2018), the authors opt for a (hypothetical) contingent valuation approach, motivated by the fact that actual SRP-certified rice does not yet exist as a product in Vietnam. Respondents freely state their maximally acceptable price for certified rice in reference to the posted price of non-certified rice. In such as open-ended elicitation, no reference prices are posted to guide participants, unlike in the payment card approach. An average price premium of 29% for SRP-compliant rice is documented, which increases with respondents' knowledge on climate change and level of household income.

A marked difference between the abovementioned studies and our WTP study concerns the economic status of the consumer sample, which is radically lower in Ruhuha. The average monthly household income in Zhou et al.'s (2017) study is US$1030 and Wang and Gao (2017) report that less than a quarter of their sampled households live on earnings below US$1135. Connor et al.'s (2022) sample is somewhat less wealthy, at an average monthly household income of US$850, but a large gap remains with rural Rwanda, where agricultural households earn US$204 on average (Smith et al. 2020). Notwithstanding this low living standard, which likely suppresses WTP for extrinsic characteristics of rice, a potential counterbalancing factor lies in the spatial proximity of consumers in Ruhuha to rice cultivation sites, such that their own community, including their own household, is likely exposed to higher health risk. This direct impact loop is arguably weaker in the Asian studies discussed here.

Methods and data

Study setting

The location of the study is the sub-district (sector) of Ruhuha, situated within Bugesera district of Rwanda's Eastern province. Despite Bugesera's proximity to the country's capital city of Kigali, at a distance of only 42 km, the district's livelihood profile remains distinctly agricultural. Four out of every five households in Bugesera depended on agriculture in the 2019/2020 season, predominantly combining crop and livestock production (NISR 2021). The most commonly grown crops are beans, maize, cassava, sweet potato and banana. Paddy rice cultivation constitutes the main livelihood of an estimated 4500 households in the district, which equals 4.3% of its agricultural households. This

exceeds the national share of 3.2%, signalling Bugesera's comparative advantage in rice. Yet, it only comes 7th out of a total of 30 Rwandan districts in terms of rice involvement.

Within Bugesera's sub-district of Ruhuha, rice cultivation is concentrated in four low-lying marshland areas, all connected to the Akagera river system. These marshlands have been shown to serve as important habitats for *Anopheles gambiae* and thus play a crucial role in local malaria transmission (Murindahabi et al. 2021). Malaria is considered endemic in Ruhuha, which experiences two malaria transmission peaks (October–November and March–May) associated with the seasonality of rains and the cycle of rice cultivation. At the time of the research (2017), Ruhuha featured among the sub-districts with the highest malaria incidence in the country; it registered over 400 cases of malaria per 1000 inhabitants (USAID 2019). The public health costs associated with such a high case rate are substantial. On average a single case costs approximately US$2.10 in diagnosis and treatment, based on a back-of-the-envelope calculation using data collected by Masimbi et al. (2022) on the ratio of simple to severe malaria cases, healthcare-seeking behaviour, and unit costs at the respective healthcare facilities in Kayonza, an equally high-endemic district in Eastern province, in 2018.

The profile above suggests that the rice-malaria nexus is more intense in Ruhuha than elsewhere in the country, and thus presents a 'critical case' (Patton 2002). Against the backdrop of falling prevalence rates in Rwanda in recent years, Ruhuha still classified among the top-4 sub-districts in terms of malaria case rate (250–450 per 1000 category) in 2020/2021 (USAID 2022). This exceeds the rate reported for several sub-districts with a higher dependence on rice. For example, Rwamagana (Eastern province) recorded fewer than 250 cases while supplying 40 per cent of the national rice supply and Huye (Southern province), where 15% of agricultural households cultivate rice, also remains below this mark.

Willingness-to-pay elicitation

Since rice with a 'malaria-free' product claim is not yet on the market, we rely on stated rather than revealed preferences for WTP elicitation, at the cost of potential hypothetical bias (Harrison 2006). The WTP elicitation format, visualised in Fig. 1, is most akin to a double-bounded dichotomous choice (DBDC), which is an iterative approach where respondents are guided towards their WTP through a sequence of dichotomous choices. Compared to the standard DBDC format, such as applied by Kajale and Becker (2015) to detect WTP for 'golden' rice in India, we build in an extra choice at higher-bid levels, creating in fact a 'triple-bounded dichotomous choice' (Venkatachalam 2004). Our motivation for a dichotomous choice format over open-ended or payment card formats is, first, that it "requires less mental effort by the respondent" (Loomis 1990, p. 84), which is relevant in a setting like ours where most respondents have little formal education. Second, it allows respondents more time to think, which has been shown to less inflated WTP statements compared to one-off formats in a developing country context (Whittington et al. 1992).

These merits outweigh the observed disadvantages of DBDC in our view, which include respondent fatigue, starting point bias, and 'yea-saying' (Venkatachalam 2004; Sajise et al. 2021). Respondent fatigue seems a minor issue with at most three choices presented per respondent and starting point bias is to some extent neutralised by

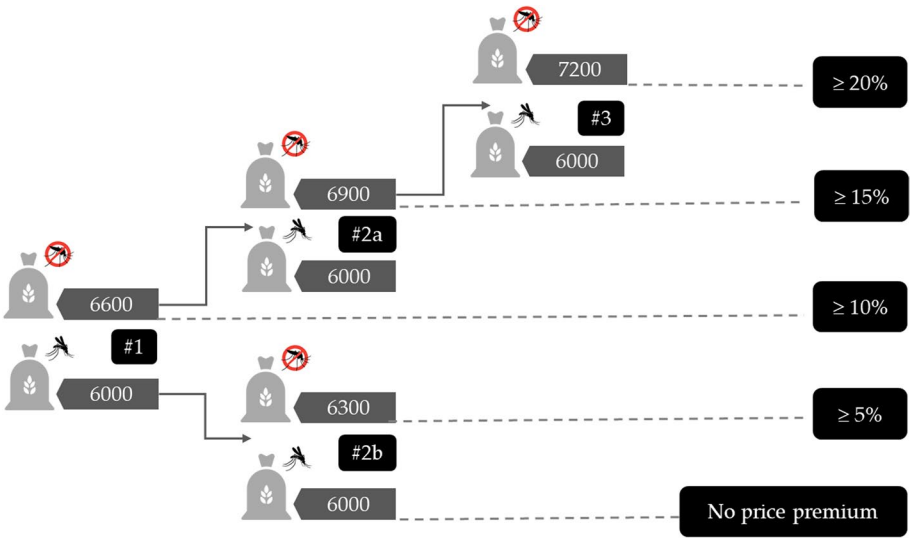

Fig. 1 Decision tree of bidding game and corresponding price premia for malaria-free rice

consumers' familiarity with purchases of rice (with a well-known base price) compared to products that constitute a real innovation to the consumer. 'Yea-saying' is a valid concern that should be acknowledged, especially in reference to those who settle for the lowest positive bid. To minimize this, the usual primer against 'cheap talk' has been included in the respondent instructions. Participants were reassured that they were not actually paying for the rice and that they would not actually receive it, but that it was important to think carefully about what decision they would make if it were for real. Note that they were cued on the rice-to-malaria pathway and *Bti* effectiveness at the start (see "Appendix 1A" for exact wording).

The decision tree in Fig. 1 illustrates the sequence of dichotomous choices presented to respondents, where the actual sequence depends on the respondent's choices in the process. Participants are first requested to imagine that they go out to the market to buy rice and encounter the following two options: (1) a 10 kg bag of rice that costs 6000 Rwandan Francs (RWF) but which is produced in a field that has not been sprayed with *Bti* larvicide and thus acts as a breeding ground for malaria mosquitoes and increasing malaria risk to the entire community; and (2) a 10 kg bag of rice that costs RWF6600 but which has verifiably been sourced from paddies that have been sprayed with *Bti*, effectively avoiding higher malaria risk in the area. The options are visualised side-by-side on a card, displaying two identical bags of rice but one showing the 'stop-mosquito' logo that also features in Fig. 1. Both bags have a 'made in Rwanda' logo in order to prevent (perceived) quality differences associated with imported rice to confound the choice. Apart from posting prices in numbers (RWF6000 or 6600) on the card, these amounts are also visualised in banknotes/coinage below the respective rice bags as an aid. The base price of RWF6000 (US$7.17) was set in accordance with observations in different market outlets in Ruhuha at the time of research.

Participants who prefer to buy the malaria-free option at 6600 in the opening choice (#1), implying they accept a 10% premium, are subsequently presented a choice problem

where the price of this option is raised to RWF6900 or 15% (#2a). If again preferred, this is raised further to 7200 or 20% in a final choice (#3) against the mainstream product at RWF6000. However, if the opening bid of RWF6600 is declined, a lower follow-up bid is offered at RWF6300 or 5% (#2b). The outcome is placement in one of five interval categories according to premium size (in %): [0, 5), [5, 10), [10, 15), [15, 20), and [20, ∞). Note that the lowest premium interval does not allow for distinguishing zero responses from non-zero responses up to 5%, and that the highest premium category is right-censored (20% or higher).

Survey

Respondent characteristics at both individual and household level were elicited in a structured and pre-coded questionnaire, which was administered prior to the DBDC procedure. Apart from covering basic demographics, it includes an elaborate module on households' socioeconomic status. Respondents were also asked to express themselves about their experiences, practices, and attitudes on malaria. This module covers, among others, ITN ownership, attitude to ITN use, perceived malaria risk, perceived responsibility of different actors in tackling malaria, and familiarity with *Bti*. A final module gathered information on rice consumption, including purchase frequency and purchase criteria (e.g., price sensitivity).

Both the survey and WTP elicitation were administered face-to-face in Kinyarwanda by a group of 10 trained surveyors of Rwandan nationality. They spent considerable time introducing the study to the respondents and explained the implications of participation in order to safeguard informed consent. The questionnaire was field-tested and back-translated in order to minimize ambiguity for both respondents and surveyors. It was designed and formatted into Open Data Kit (ODK) Collect setup on tablet devices, such that responses were immediately and securely uploaded on a local server.

Sample

Ruhuha hosts an estimated 5000 households, comprising approximately 25,000 individuals, across a total of 35 villages (*imidugudu*). The sampling strategy of households for the WTP elicitation consisted of two stages; a purposive sample of 10 villages from this frame and, subsequently, a random (quota) sample of 30 households per selected village. Village selection was guided by proximity to rice cultivation sites, and more specifically, to those marshlands that were part of a six-month bio-larviciding pilot co-implemented by the first author in 2015. The purpose was to detect whether WTP for malaria-free rice is mediated by exposure to rice fields as well as to prior application of *Bti* in these fields. This results in the following three sets of villages: (a) 4 villages that have no rice cultivation site nearby (> 1.5 km); (b) 2 villages close to rice cultivation sites that were not sprayed with larvicides, and (c) 4 villages close to rice cultivation sites sprayed about 1.5 years prior to WTP elicitation. Within the latter group, a further distinction is made between villages where the larviciding pilot was intensively supervised by outside experts (2 villages) and those where *Bti* application was self-organized by the community (2 villages). This distinction should cater for the possibility that the perception (and recall) of larviciding success varies with the intervention modality used in the pilot.

Table 2 lists the 10 villages that constitute the sample, clustered into four 'zones' as described above. Regarding zone 1, more than four villages were sufficiently distant from rice cultivation to be eligible for sample inclusion, upon which we opted for selecting those four villages that best represented the range of village-level malaria incidence rates across Ruhuha, as recorded in a 2013 baseline study in which the first and second author were involved. The village of Kiyovu featured one of the highest malaria incidence rates, while that of Ruhuha I was among the lowest.

Table 2 Sample overview and living standard profile per village (indicating best (bold) and worst (italic) performance per metric)

		Living standard metrics (study participants only)				
		Ratio of sampled to actual households	**Wealth index**	**Multidimensional poverty index**	***Ubudehe* category**	**Able to save past 3 months**
			[− 14, 14] (< 0 = shortfall)	**(Headcount x intensity)**	**0-1-2 (poorest = 0)**	**0 = No 1 = Yes**
Zone	**Village**	***n/N***	**Mean**	**Mean**	**Mean***	**%**
Zone 1: *no rice cultivation (no marshland)*						
40.0%	Ruhuha I	29/185	0.55	0.34	1.29	0.10
	Kimikamba	28/172	**2.82**	**0.20**	*0.75*	0.14
	Kazabagarura	30/127	− 0.63	0.40	1.30	0.20
	Kiyovu	29/136	− 0.72	0.41	1.44	*0.03*
Zone 2: *rice cultivation in marshland, no larviciding*						
20.0%	Nyaburiba	28/112	− 0.64	*0.45*	1.46	0.14
	Rwanzunga	30/151	1.50	0.28	1.61	**0.43**
Zone 3: *rice cultivation in marshland, larviciding under expert supervision*						
20.3%	Kibaza I	30/173	*− 1.40*	0.38	**1.66**	0.10
	Kibaza II	29/96	− 1.14	0.44	0.97	*0.03*
Zone 4: *rice cultivation in marshland, community-based larviciding*						
19.7%	Rutare	30/145	0.07	0.40	1.31	0.13
	Gikundamvura	27/134	1.11	0.33	1.56	0.19
Total sample		290/1432	0.13 (3.46)	0.37 (0.16)	1.33	0.15

*9 missing observations ($n = 281$). Standard deviations for total sample provided in parentheses (bottom row), for wealth and MPI index only

The entire set of sampled villages hosts 1432 households, i.e., close to 30% of the subdistrict population. The recommended sample size for a contingent valuation WTP format with five bid levels and a research population of 1500 is 300 observations (Gunatilake et al. 2007). Per village a random walk technique was used to approach 30 households for participation, ignoring the variation in population size as reported in Table 2. Note that households involved directly in rice cultivation were not eligible. In ten households, spread over 6 villages, respondents turned out to have hardly any experience in buying food, but stepped forward in absence of the main decision-makers on the household budget, so that these households were eventually dropped from the sample. All other households met the criterion of being represented by an adult member who had bought rice at least once in the past year and exercised some control over household food expenditure. The resulting sample therefore covers 290 households, or 20.1% of the population under study. In some cases, respondents felt more comfortable participating in the presence of other household members, often their partner, which was allowed. The bystander's influence on the (main) respondent's WTP decision was not strictly monitored, as this likely mimicked the typical (joint) decision-making process on food purchases within the household.

The wealth profile of the sample warrants special attention, as we test whether rural consumers in a low-income country can afford (and are willing) to pay ethical price premiums. In order to be able to isolate the effect of economic status on WTP from the effect of proximity to rice cultivation and exposure to a larviciding campaign, the wealth status of the sampled respondents should not systematically correlate with the zonal classification in Table 2 but rather show substantial within-group variation. To inspect this, we use four alternative (but partly overlapping) metrics of household economic status. First, we constructed a wealth index that reflects the degree of deprivation of a household locally, benchmarked against the typical living standard in the area on a set of 14 indicators. Second, we replicated the capability-inspired Multidimensional Poverty Index (Alkire and Santos 2014), which concentrates on the domains of health, education, and material living standard. It counts sufficiency/deficiency over 10 indicators. A cut-off is used to determine whether a household is multidimensionally poor, in which case the intensity of deprivation is assessed. The third metric is one's (self-reported) classification in Rwanda's home-grown *Ubudehe* system of wealth differentiation (Sabates-Wheeler et al. 2015). This bottom-up classification relies on participatory wealth ranking and is used by the Rwandan government for targeting its social protection policies. We collapse the system's six-step wealth ladder into three categories. Our final wealth measure is also self-reported, but concerns a single indicator. It focuses directly on surplus income by asking whether the household is able to save money or not. More detail on the operationalization of each metric is provided in "Appendix 1B".

Table 2 shows the group means for the four wealth metrics per village-specific respondent pool. A first observation concerns the low degree of consistency in village performance across the different measures. For example, Kimikamba (zone 1) is the best-performer on the wealth index and the MPI, but the worst-performer if the local *Ubudehe* classification is considered. Inversely, Kibaza I outperforms all other villages in the participatory ranking system, but at the same time features the lowest score on the wealth index. A second observation is that none of the sampling zones stands out as

holding high uniformity in either relatively low or high wealth levels, as each zone presents clear inter-village variation on at least one of the metrics. This reduces the risk of confounding the effect of economic status with that of proximity to (sprayed) rice fields.

Data

Descriptive statistics on the background characteristics of our sampled respondents are provided in "Appendix 2A", which inform the profile below. Young adults and men are underrepresented, following the sampling criterion of being tasked with rice purchases. About 60% of respondents are over 35 years and women constitute roughly two-thirds of the sample. The typical household in the sample is a five-member family of two spouses, two children aged between 5 and 18, and one under-five child. Yet, one-fifth of the households is female-headed following either widowhood or separation. About 9% of the households experienced loss of a member in the five years prior to the survey. Three of these fatalities, all concerning under-five children, were reportedly caused by malaria.

Awareness of malaria prevention through the use of ITNs is almost universal. No less than 97% deems consistent ITN use "very important", matched with an 86% ownership rate of ITNs. Still, half the sample rates the frequency of being bitten by mosquitoes in or around the homestead as either "often" or "very often" and a similar proportion considers malaria a "very serious" risk compared to other health risks. Roughly a third of the sample (36%) indicates to be familiar with the work of Community Malaria Action Teams (CMATs). These teams, consisting of a local leader, youth representative, and community health worker, were set up to sensitize residents on preventive practices against malaria in each village (Ingabire et al. 2019). A marginally higher share (40%) is aware of the existence of *Bti* as a biological larvicide to be applied in mosquito breeding sites for malaria control. The *Bti* pilot carried out in multiple rice cultivation sites in 2015 has likely been instrumental in fostering this level of exposure. Despite wide recognition that rice cultivation presents a critical node in the malaria transmission chain (79%), the respondents do not squarely put the burden of malaria control on local farmers. Their degree of responsibility for tackling malaria is scored 6 on a 10-point scale, where 10 represents maximum responsibility. Local actors in general, comprising both leaders and ordinary people, carry a stronger responsibility (7.3) than the farmer subgroup only. Yet, first-line responsibility for malaria control falls on actors beyond the local realm, i.e., the national government and international donors (8.6).

With respect to rice consumption, the usual point of purchase is either the store (60%) or the open-air market (30%). The remaining 10% obtains rice directly from individual farmers, farmer cooperatives or rice millers. Except for one household, all acquire rice from an outlet within the Ruhuha area itself. Purchase frequency and quantity vary considerably, but the most common pattern is to buy one-monthly, and the single-purchase quantity in this group amounts to an average of 3.4 kg (from a range of 1–25 kg). Price and convenience are the most important criteria for outlet choice, which are considered "very important" by 84% and 58%, respectively. Against the national trend of rising per capita rice consumption, 56% report to have reduced their consumption of rice over the three years up to the survey, while only 17% confirms to have been on an upward consumption trend. It needs to be stressed that rice does not qualify as a staple food like beans or cassava for most of the households under study. One in three (33.8%) of the

sampled families cook rice at least once a week, but a similar proportion (32.8%) prepares a rice-based meal once or twice a month, and the remaining third (33.4%) consumes rice even less frequently, i.e., on festive occasions only.

Applying a wealth gradient to rice consumption confirms that rice is in fact a luxury food for many families in Ruhuha. Among the bottom quartile of our wealth index, only 10.1% reports weekly rice consumption, while this share increases to 43.8% among the top quartile. Breaking down the frequency of rice consumption by multidimensional poverty score (MPI), or a household's ability to save, shows similar divergence by economic status. Only the local *Ubudehe* categorization, which may take in unobserved household characteristics that compound long-term economic vulnerability, such as disability or trauma, shows a weaker correlation with rice consumption. Among the poorest category (*umutindi*), representing 17.4% of the sample, weekly rice consumption is more than 10 percentage points higher than among the bottom quartile on the wealth index.

The degree of representativeness of our consumer sample for the wider Ruhuha community is briefly explored in "Appendix 2B". It compares selected descriptive statistics with those reported in Rulisa et al. (2022) for a larger set of Ruhuha residents, which, conveniently, also excludes rice-cultivating households. Values on all indicators suggest reasonable to strong representativeness, but our sample underperforms on household wealth. Since the same wealth index is used, it seems safe to infer that our sample is not biased towards wealthier consumers, rather the opposite. This likely builds a degree of conservativeness into our WTP estimation.

Data analysis

The appropriate data analysis technique to predict WTP from respondent characteristics in DBDC formats is interval regression (Sajise et al. 2021). An interval-data model is more efficient than an ordered logit or probit model, as it considers the actual WTP cut points used in the DBDC, which remain implicit otherwise. Also, compared to ordinary least square (OLS) regression, it acknowledges the uncertainty about exact WTP values within a given interval and can adequately handle the right-censoring of WTP bids in the upper tail (Yang et al. 2012).

We estimate seven interval regression models using the same dependent variable, i.e., the ordered interval scale of stated premiums for 'malaria-free' rice (in percentage over base price) generated from the DBDC. A fixed sub-set of independent variables across the models include demographics, sample zone, malaria-related variables, and purchase criteria of rice. However, on living standard, the four different wealth metrics (see Appendix 1B) are included separately (models 1, 2, 3 and 5 in Table 3). It is unclear, a priori, which metric should be expected to hold most explanatory power. A model has been added that includes rice consumption frequency, but omits any other wealth indicator, given the steep wealth gradient that underlies a family's rice intensity in meals (model 4). However, such risk of confounding effects remained within conventional tolerance levels when including the *Ubudehe* classification (as a dummy variable identifying the poorest category) alongside both rice consumption frequency (model 6) and a household's ability to save (model 7). Note that some observations on *Ubudehe* classification are missing, so that inclusion implies 281 rather than 290 observations. The models are presented in ascending order of fit in Table 3, as informed by the Likelihood Ratio (chi-square) test.

Table 3 Interval regression models on consumer price premium for rice cultivated with use of biological larvicides

	Interval regression coefficients (standard errors)						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Demographics							
Age respondent	−1.50 (2.74)	−1.23 (2.70)	−0.97 (2.83)	−0.10 (2.74)	−1.02 (2.68)	0.30 (2.87)	−0.45 (2.80)
Male respondent	29.49 (31.33)	11.75 (76.46)	21.90 (78.51)	10.06 (76.10)	11.02 (75.84)	6.19 (78.43)	1.68 (77.91)
No. of household members	20.01 (31.3)	11.75 (30.67)	28.42 (32.10)	14.02 (30.09)	25.55 (30.16)	21.44 (31.74)	30.03 (31.63)
No. of children < 18 years	−68.87* (39.35)	−63.79* (38.30)	−84.28** (40.59)	−58.77 (37.85)	−70.16** (37.99)	−74.21** (40.03)	−81.09** (39.97)
No. of children < 5 years	93.99* (56.58)	92.22 (56.06)	109.58* (57.80)	85.91 (55.81)	91.25 (55.85)	99.80** (57.45)	104.45* (57.21)
Sample zone (ref: zone 1; area without marshland—no rice cultivation)							
Zone 2: non-sprayed rice cultivation	79.64 (99.96)	81.05 (98.69)	91.50 (101.76)	110.39 (99.09)	43.91 (98.67)	129.15 (102.74)	65.00 (101.02)
Zone 3: sprayed rice cultivation (expert-led)	−76.26 (104.87)	−45.60 (104.63)	−91.62 (105.82)	−13.30 (105.51)	−51.67 (102.96)	−32.33 (108.28)	−64.50 (104.72)
Zone 4: sprayed rice cultivation (community-based)	−84.23 (104.94)	−89.37 (103.75)	−102.99 (105.30)	−31.09 (105.23)	−84.85 (103.14)	−53.73 (106.93)	−100.54 (104.03)
Knowledge, attitudes, behavior, experiences related to malaria (control)							
ITN ownership	−176.16* (105.58)	−202.90* (104.92)	−208.03* (106.40)	−192.72* (103.48)	−192.27** (103.15)	−218.38** (106.02)	−225.32** (105.44)
Importance of consistent ITN use (1 = low; 2 = medium; 3 = high)	202.19 (196.93)	218.18 (195.71)	185.57 (197.77)	192.06 (194.99)	226.06 (194.89)	178.95 (196.80)	207.40 (195.87)
Perceived frequency of mosquito bites around homestead	−37.43 (58.63)	−36.65 (58.13)	−53.52 (59.27)	−32.26 (57.92)	−37.69 (57.83)	−49.09 (58.99)	−49.45 (58.66)
Perceived risk of malaria to own household (1 = low; 2 = medium; 3 = high)	18.43 (68.56)	15.13 (68.08)	22.46 (69.16)	14.09 (67.81)	13.87 (67.65)	15.88 (68.85)	15.33 (68.36)
Household member deceased in past 5 years	−357.84*** (129.46)	−335.29*** (127.27)	−388.04*** (129.81)	−332.05*** (126.33)	−358.18*** (125.73)	−348.01*** (130.05)	−386.16*** (128.32)
Aware of Community Malaria Action Teams (CMATs)	134.36* (77.96)	123.41 (77.15)	140.42* (78.93)	122.68 (76.89)	134.38** (76.69)	132.95* (78.54)	145.41* (78.03)
Aware of *Bti* (larvicide)	103.85 (82.07)	101.50 (81.52)	112.70 (83.59)	81.09 (81.45)	100.68 (80.83)	98.13 (83.31)	111.94 (82.43)
Perceived responsibility for actor(s) in malaria control							
(Inter)national actors; Rwandan government + international donors	−4.41 (13.44)	−0.09 (13.41)	0.77 (13.55)	−2.60 (13.23)	−6.01 (13.15)	2.68 (13.53)	−0.33 (13.38)
Local actors; 'leaders' + 'people'	33.41** (12.93)	34.14*** (12.80)	31.57** (13.34)	39.77*** (13.02)	32.75** (12.70)	36.24*** (13.46)	30.98** (13.16)

Table 3 (continued)

	Interval regression coefficients (standard errors)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Farmers	− 26.13 (17.04)	− 28.02* (16.89)	− 25.99 (17.21)	− 33.94** (17.12)	− 24.55 (16.73)	− 32.21* (17.39)	− 24.62 (16.97)
Rice purchase decision							
Price sensitivity	− 154.72** (71.84)	− 144.04** (70.71)	− 173.87** (73.30)	− 123.48* (71.25)	− 137.89** (70.29)	− 146.21** (73.85)	− 161.10** (72.47)
Convenience sensitivity	− 77.77* (40.02)	− 76.67* (39.69)	− 84.86** (40.51)	− 85.56** (39.72)	− 82.52** (39.51)	− 91.56** (40.44)	− 89.97** (40.08)
Frequency of rice consumption				85.48*** (31.01)		72.19** (32.58)	
Living standard							
MPI score	− 73.11 (248.24)						
Wealth index		22.81** (11.00)					
Classified as *umutindi* (lowest category in *Ubudehe* system) [1 = yes; 0 = no]			− 164.51* (96.15)			− 145.86 (95.76)	− 147.70 (94.93)
Ability to save money (past 3 months) [1 = yes; 0 = no]					302.20*** (103.56)		296.28*** (105.40)
No. of observations LR test statistic (X^2)	290 40.53***	290 44.77***	281 46.52***	290 48.14***	290 49.16***	281 51.48***	281 54.61***

Dependent variable is stated consumer price premium (interval scale) across all models. Standard errors are provided in parentheses. Overall model performance evaluated by Likelihood Ratio (LR) test. ***, **, and * denote significance at 1%, 5% and 10%, respectively

All models significantly outperform 'empty' models, so that the set of predictors as a whole is meaningful in understanding variation in WTP.

Results

The WTP bidding resulted in the following distribution on the premium interval ladder. In descending order of group size, 31.7% supports a price premium of 20% or higher, which represents the top category of premium payers. The second-largest share (22.8%) is located in the [10, 15) interval and a slightly smaller share (19.7%) in the [15, 20) interval. This implies that close to three in four (74.2%) would reportedly accept a mark-up of 10% (RWF600 [US$0.72]) on a 10 kg bag of rice if cultivated in paddies with effective larval source management. The fourth-largest group (15.5%) ranks at the bottom of the ladder and does not pass the 5% premium threshold. Hence, this group is not (or only minimally) willing or able to pay extra for sprayed rice. The remaining 10.3% of the respondents settle for a modest premium in the [5, 10) interval. On the conservative assumption that all respondents would only accept the lower bound of the interval in which they are categorized, mean WTP in the sample equals 12.1% over the base price. By comparison, this fits into the range of a 9–33% average premium for VietGap-certified

rice reported by My et al. (2018) for Vietnam, despite the wide gap in wealth between rural Rwandese and urban Vietnamese households.

Table 3 investigates which factors are significant predictors of premium payment. In terms of demographics, neither the age nor gender of the respondent has significant explanatory power. The same applies to household size, while household composition matters. Having children in the 5–18 age category appears a disincentive for higher premium payment (negative and significant in all but one of the models), while having under-five children tends to have the opposite effect (positive and significant in four models). This may be explained by the fact that under-fives are at a higher risk of malaria-related mortality, motivating premium payment, while it is also conceivable that such a health premium competes more sharply with pressing expenses for older children (e.g., school fees).

One of the hypotheses of interest concerned the impact of a household's proximity to rice cultivation and exposure to past larviciding campaigns, either self-organized or externally supervised. None of these treatment aspects show a significant impact on WTP, however. If anything, a weak tendency towards lower premiums is observed among residents of villages close to rice fields that were sprayed (negative but insignificant coefficient in all models), but this is likely mitigated by a weak positive effect from higher *Bti* awareness (positive but non-significant coefficient in all models) in sprayed zones. The proportion that has heard about *Bti* in the latter (74%) exceeds that in the non-sprayed and non-rice zones by 20 and 50 percentage points, respectively.

Some of the malaria-related variables appear more important than one's familiarity with rice cultivation and bio-larviciding in terms of predictive power. This holds for ITN ownership, for example, which enters negatively and significantly. Unless one accepts a trade-off between investment in personal protection and contribution to collective protection, this is a counterintuitive result. Strikingly, having lost a family member in the recent past strongly suppresses WTP. While these fatalities may not be malaria-related in most cases, one would expect such experiences to make health risks more salient and thus stimulate WTP. Tentatively, this signals a fatalistic attitude fostered by recent loss. The perceived seriousness of malaria risk for one's own household, the self-reported level of mosquito nuisance, one's level of commitment to ITN use, and one's familiarity with the CMATs fail to emerge as relevant predictors. Respondents' allocation of responsibilities for malaria control, on the other hand, systematically drives WTP variation. Those who shift responsibility onto farmers are less willing to contribute themselves (significant in three models), while higher contributions follow from assigning strong responsibility to local communities (significant in all models), which we interpret as playing one's part as local consumer in response to notions of collective responsibility.

A household's attitude towards rice purchase criteria is also influential. While it may not surprise that significantly lower premia are recorded for the most price-sensitive households, respondents who stress the importance of convenience attributes also tend to settle for a lower premium (significant in all models). This either suggests that consumers entertain doubts as to whether malaria-free rice will be available in their preferred outlet, or signifies that convenience shoppers are generally not keen to invest resources in optimizing their food purchase choices. Rice consumption frequency has a distinct positive effect on the premium when entered into the model without wealth

metrics (model 4). A comparison across models reveals that consumption frequency picks up on wealth differences rather than acts as an intrinsic motivator.

Each of the four wealth metrics carry the expected sign, but their effect size varies notably. The MPI is the weakest predictor, being the only one that does not reach significance. By contrast, a household's ability to save is the strongest predictor, despite its relative simplicity as single-indicator measure. Combining savings ability with the homegrown *Ubudehe* classification offers the best fit overall, outperforming the model that includes rice consumption frequency alongside *Ubudehe* classification. This is suggestive of premium payment being conditional on households' current surplus income as well as the underlying capacity to remain financially healthy in the future. The community-based wealth ranking arguably offers better insight into the latter aspect than alternatives focussed on basic needs fulfilment.

This positive relation between household wealth and premium payment aligns with positive income effects encountered in the WTP studies for eco-friendly rice in China (Wang and Gao 2017; Zhou et al. 2017). Another parallel consists in the counterintuitive finding that malaria risk perceptions do not emerge as a significant determinant of WTP in Table 3. One would expect higher perceived risk to increase WTP for malaria-free rice. Among Wang and Gao's (2017) participants, perceptions of higher environmental risk also fail to induce a higher premium for eco-labelled rice. They reckon that premium payers are not risk-driven, but rather motivated by strong personal commitment to act upon environmental goals. The higher WTP among those Ruhuha consumers who confer responsibility for a malaria-free environment on 'the people' might be a reflection of such personal commitment. In further support of personal value-driven motivation, Zhou et al. (2017) find that performing environmental-friendly routines outside of the marketplace serves as 'catalyst behavior' and translates into higher WTP for eco-labelled rice. In our case one might assume that participants' commitment to the use of ITNs would hold such a catalytic potential, yet the non-significance of this variable in our analysis casts doubt on whether such 'habit spillovers' operate in Ruhuha.

Discussion

This section evaluates the feasibility and desirability of a VSS for malaria-free rice in Rwanda by focussing on two criteria: effectiveness and equity. Effectiveness refers in this context to market viability, while the equity criterion calls for a reflection on the distributional consequences among farmers and consumer segments if a VSS would come off the ground. On the effectiveness count, it should first be observed that Rwandan consumers have so far been hardly exposed to food choices involving sustainability labels. The catalogue of the International Trade Centre reveals that out of the 324 existing agricultural standards that involve product labels, 12 operate in Rwanda (ITC 2021). These exclusively concern export commodities like coffee and tea (see Elder et al. 2013, and Wamukui et al. 2015, for evaluations), which echoes Gregson and Ferdous' (2015) observation that countries in the Global South only play a part in ethical value chains in their capacity as producers, overlooking domestic consumers. Yet, the results from our consumer sample in Ruhuha appear to belie the assumption that a price premium for socially responsible rice would be self-defeating due to lack of purchasing power. Even though the willingness to pay extra for malaria-free rice is likely an upper bound, given

the hypothetical nature of our choice experiment, support is broad (85%) and for a substantive share it is rather deep (almost one-third paying up to 20% extra). An intriguing feature of this health-related externality is that, upon initial success, the required premium to cover larviciding cost may shrink due to a positive feedback effect on productivity. For example, Madaki (2017) finds among a sample of Nigerian farmers involved in crop agriculture, including rice, that the output of farmers who did not experience malaria was 20% higher compared to that from those affected by malaria. The latter recorded an average of 16.6 days of incapacitation over the timespan of a year. Hence, a VSS may prove self-sustaining over time if productivity gains reduce price.

At the same time, concerns about the feasibility of a VSS crop up. First, participants may have been driven towards a premium in the belief that they would benefit personally from lower malaria risk rather than being motivated by societal interest. The result that ITN ownership reduces WTP hints that one's personal stake is a relevant driver. This raises the question whether the same experiment among Rwandan consumers who are more distant to rice cultivation areas, or who are better protected against malaria (e.g. in urban housing), would generate similar WTP levels. Another potential caveat relates to the market for rice in Rwanda itself. Nationally produced rice competes with imported rice from Asia, especially Pakistan and Thailand, as well as from neighbouring Tanzania. While the price gap between local and foreign rice tends to be wide, a national VSS would reduce this gap and may induce the least price-sensitive consumers to switch to imports. This is a particular concern with respect to Tanzanian rice, also referred to locally as "Super Rice", which is highly coveted because of its taste and smell, but also for its superior capacity to expand during cooking, which means a lower quantity needs to be prepared (Nsanzimana 2019).

Competition from imports suggests that the scale of a VSS should be international. Lobbying the Sustainable Rice Platform (SRP) to include malaria mitigation in its global standard seems a long shot, as the platform is dominated by Asian producers where malaria is not a health priority. A regional initiative might be worth exploring instead, for example under the auspices of the Coalition for African Rice Development (CARD), a consultative group of bilateral donors and regional and international organizations working with 32 rice-producing countries in Africa, including Rwanda. Its current ambition is to double rice production in sub-Saharan Africa between 2019 and 2030. Early 2020 an East African rice platform was launched between the East African Community (EAC) and CARD, which is currently drafting a rice development strategy for the region. This presents an opportunity to take steps towards formulating a voluntary standard that takes malaria risk seriously. For example, one of the EAC members is Tanzania, which has a strong track record on (community-based) larval source management (see Fillinger et al. 2008, for early experiences). Moreover, it is the only country from the 32 CARD members that explicitly acknowledges the risk of malaria in its national rice development strategy for the current decade (MALF 2019, p. 47). One of the main issues on the agenda should be the monitoring of VSS compliance on the part of 'certified' rice cooperatives in order to gain and maintain credibility of the product label for the consuming public.

If implementation of a VSS proves feasible, desirability is also conditional on its implications for equity. A well-known risk of VSS is that the largest producers are able to jump

on the bandwagon, leaving the smallest producers behind and thereby fuelling inequality. However, this risk is attenuated in the case of Rwandan rice, as farmer cooperatives rather than individual farmers are likely to sign up. Such group certification generally offers more equal access to VSS schemes (Pinto et al. 2014). Note that rice cooperatives in Ruhuha tend to host a mix of large and small farmers (Rulisa et al. 2021). On the consumer side, equity considerations do not pose a major concern either. Our results predict that a successful VSS will work as a progressive tax, at least among rural consumers, as the diet of the poorest only contains rice occasionally. Hence, better-off families who tend to consume rice on a weekly basis will be impacted most by a higher price.

Conclusions

In response to a call to involve local rice consumers in tackling the negative public health externality that is created in rice paddies, this paper explored the willingness of rural rice consumers in Ruhuha, Rwanda, to contribute financially towards malaria risk reduction. We tested whether they were willing to pay a price premium for rice cultivated in fields sprayed with bio-larvicides using a double-bounded dichotomous choice format. While consumers in the Global South, especially beyond the urban elite, remain conspicuously absent in the literature on ethical consumerism, our results challenge the underlying assumption that they lack the means to make costly choices in favour of the public good. Both on the extensive margin (85% are potential premium payers) and the intensive margin (74% accepts a 10% premium) the outcomes are encouraging.

Some caution is warranted when translating these results directly into actual resource mobilisation, however. This not only concerns the well-documented attitude-behaviour gap when moving from a hypothetical to a real purchase situation. A lack of support from consumers in low-endemic areas could undermine WTP in high-endemic ones like Ruhuha. Moreover, the complex malaria epidemiology implies that malaria incidence may not vary proportionally with the intensity of larviciding efforts, which may confuse perceptions of effectiveness. Finally, competition from imported rice presents another unknown factor.

Yet, the study sample shares some characteristics of 'citizen-consumers' (Mehrabi et al. 2022), as they willingly take co-responsibility for the societal impact of (food) consumption. This seems an important precondition for building collective consumer activism over time, which would imply "a sense of partnership and a sense of ownership—thus food citizenship" (ibid., p.12). Consumers in Ruhuha, with the notable exception of the poorest-of-the-poor, not only identify with the problem that occurs in the stage of rice cultivation, but also express a sense of moral obligation to be part of the solution, even if this requires stretching already tight budgets. In case this willingness would not be fully carried through in actual market behaviour, the intention might still be of symbolic importance to the rice farming community, whose commitment to larviciding campaigns may hinge on broader community support.

Ideally, the government, donors, private business (e.g., larvicide producers and rice millers), and/or social investors would step in to bolster such a shared responsibility model between farmers and consumers. Investment of economic and political resources by these actors is particularly crucial in an eventual scale-up phase towards a credible voluntary sustainably standard for malaria-free rice at the regional level. Crowding in

the full array of stakeholders that are part of, or affiliated to, the rice value chain, including the consumer segment, would raise the prospect of sustainable larval source management. In turn, this could effectively re-align agricultural development and public health in malaria hotspots like Rwanda's rice-cultivating areas.

Appendix 1: Additional information on methods

1A. Introduction text for study participants (read out by interviewer) concerning the local rice-malaria nexus

Research in Ruhuha sector has identified rice fields as one of the main breeding sites for mosquitos, as rice fields offer stagnant water that mosquitos like so much. Luckily, something can be done against this in the form of spraying Bti larvicide on the rice fields. Bti is a biological agent and therefore does no harm to other animals nor to the rice plants, and is perfectly safe to farmer and consumer. We know that Bti effectively reduces the number of mosquitos, including those that transmit malaria, and this has been tested here in Ruhuha also. However, Bti-spraying is costly, so if rice farmers will have to buy the larvicide and apply it, rice will become more expensive as a result.

1B. Operationalization of household wealth status metrics

(1) *Wealth index*; The index consists of fourteen indicators clustered around the following aspects: asset ownership (house [1], land [2], livestock [3]), basic household amenities (type of sanitation [4], sources of drinking water [5], lighting [6] and cooking [7]), housing materials (floor [8], walls [9] and roof [10]), financial status (source of income [11], ability to save [12], and ability to pay for medical care [13]), and household diet (combination of frequency and type of food items consumed [14]). On each item, we first identified the modal response as the standard, which implied a zero sub-score. Households that fall short of the standard score a value of -1, while those who exceed the standard are assigned a value of 1. A household's overall wealth index score then equals the sum of scores over all fourteen items, ranging from -14 (most deficient) to 14 (most comfortable).

(2) *Multidimensional poverty index* (MPI); consists of 10 indicators covering the dimensions of health (nutrition [1], child mortality [2]), education (enrolment [3], level attained [4]), and living standards (adequate housing [5], asset ownership [6], access to water [7], sanitation [8], electricity [9] and cooking fuel [10]). We followed the MPI logic of scoring a household's deficiency as 1 (and sufficiency as 0) for each indicator. Households are considered multidimensionally poor if they experience deficiencies in more than one-third of the weighted indicators, where the weight of an indicator is lower if the total number of indicators covering the dimension to which it belongs is higher, so as to maintain equal weighting across the three dimensions. The MPI score of a poor household is then expressed as the percentage of weighted indicators on which it experiences deficiency, while that of a non-poor household is censored to zero. Aggregation over multiple households thus implies that the MPI value of a village is the product of poverty headcount and deprivation intensity of the poor.

(3) *Ubudehe category*; self-report of wealth category assigned through community participatory techniques, mandated by the Rwandan government. Households are typically well-aware of their category, as it determines, among others, their co-payment for community health insurance. In Ruhuha's rural context it is possible to collapse the six original *Ubudehe* categories with only marginal loss of information into an ordinal variable with three wealth classes: low/*umutindi* (0), medium/*umukene* (1), and high/*umukungu* (2).
(4) *Savings ability*; Respondents were asked whether their household had been able to save money over the past three months and are assigned 1 if yes, or 0 if not.

Appendix 2: Additional information on data

2A. Descriptive statistics of selected variables included in interval regression

(a) Price premium interval categories (dep.var.)	%	(f) Frequency of rice consumption		%
$x < 5\%$	15.5 ($n = 45$)	Occasionally (< once per fortnight)		33.4 ($n = 97$)
$5\% \leq x < 10\%$	10.3 ($n = 30$)	Once per fortnight		32.8 ($n = 95$)
$10\% \leq x < 15\%$	22.8 ($n = 66$)	Once per week		12.1 (n = 35)
$15\% \leq x < 20\%$	19.7 ($n = 57$)	2–3 days per week		17.2 ($n = 50$)
$x \geq 20\%$	31.7 ($n = 92$)	$\geq$ 4 days per week		4.5 ($n = 13$)
(b) Demographics	mean	st.dev	min	max
Age respondent (in years)	41.8	14.8	20	79
Male respondent	0.33	–	0	1
No. of household members	4.7	2.1	1	12
No. of children < 18 years	2.5	1.7	0	9
No. of children < 5 years	0.8	0.8	0	3
(c) Knowledge, attitudes, behavior, experiences related to malaria (control)				
ITN ownership	0.86	–	0	1
Importance of consistent ITN use during nights (1 = low; 2 = medium; 3 = high)	2.97	0.17	2	3
Perceived frequency of mosquito bites around homestead (1 = almost never,.., 4 = very often)	2.54	0.72	1	4
Perceived risk of malaria to own household (1 = low; 2 = medium; 3 = high)	2.42	0.57	1	3
Household member deceased in past 5 years	0.09	–	0	1
Aware of Community Malaria Action Teams (CMATs)	0.36	–	0	1
Aware of *Bti* (larvicide)	0.40	–	0	1
(d) Perceived responsibility for actor(s) in malaria control (0–10 scale; 10 = highest responsibility)				
(Inter)national actors; Rwandan government + international donors	8.55	1.48	3	10
Local actors; 'leaders' + 'people'	7.34	1.67	1	10
Farmers	5.98	2.50	0	10
(e) Importance of decision criteria in rice purchase (1 = low; 2 = medium; 3 = high)				
Price	2.78	0.55	1	3
Convenience	2.22	0.94	1	3

2B. Comparison of sample to broader Ruhuha population on selected background variables

	Consumer sample (this paper)	Broader Ruhuha sample (data from Rulisa et al. 2022)*
Rice-cultivating households excluded	Yes	Yes
Coverage	10 villages	35 villages
No. of observations (households)	290	3786
Age respondent (in years), mean	41.8	43.0
No. of household members, mean	4.7	4.3
Primary school not completed, share	0.37	0.36
Female-headed households, share	0.20	0.27
Main livelihood is agriculture, share	0.84	0.83
ITN ownership, share	0.86	0.93
Wealth index, mean score [− 14, 14]	0.13	1.36
Low wealth status, share [− 14 ≤ score < 0]	0.44	0.30
Medium wealth status, share [0 ≤ score < 5]	0.45	0.51
High wealth status, share [5 ≤ score ≤ 14]	0.11	0.19

*Data on individual variables concern heads of household

Abbreviations

Bti	*Bacillus Thuringiensis* var. *Israelensis*
CARD	Coalition for African Rice Development
CD	Communicable disease
CGIAR	Consortium of International Agricultural Research Centers
CMAT	Community malaria action team
DBDC	Double-bounded dichotomous choice
EAC	East African Community
GDP	Gross domestic product
IRRI	International Rice Research Institute
ITNs	Insecticide-treated nets
MPI	Multidimensional poverty index
NCD	Non-communicable disease
ODK	Open Data Kit
RWF	Rwandan Francs
SRP	Sustainable Rice Platform
VSS	Voluntary Sustainability Standard
UNEP	United Nations Environment Programme
WTP	Willingness-to-pay

Acknowledgements
We would like to thank all Dutch and Rwandan partners in this research project and are particularly grateful to the study participants in Ruhuha for their kind cooperation.

Author contributions
AR, LK, and DJK jointly conceptualized the study and designed the empirical strategy. AR collected and curated the data, supported by LK. AR and LK performed the data analysis and drafted the first version of the manuscript, which was reviewed and edited by DJK. All authors read and approved the final manuscript.

Funding
This study was funded by WOTRO Science for Global Development, grant number W07.45.101.00. The funding agency did not participate or play a role in the design of the study.

Availability of data and materials
All data, transcripts, and supporting documents for this study are stored at the Data Repository of Radboud University, which can be made available upon request to the corresponding author.

Declarations

Ethics approval and consent to participate
This study was approved by the Rwanda National Health Review Committee on 2 December 2013 (NHRC/2013/PROT/0125) and the Rwanda National Ethics Committee on 23 January 2014 (N°002/RNEC/2014). Written informed consent was obtained from all participants prior to data collection.

Competing interests
The authors declare that they have no competing interests.

Received: 24 January 2023 Revised: 28 July 2023 Accepted: 31 July 2023
Published online: 17 August 2023

References

Alkire S, Santos ME (2014) Measuring acute poverty in the developing world: robustness and scope of the multidimensional poverty index. World Dev 59(July):251–274. https://doi.org/10.1016/j.worlddev.2014.01.026
Burkett-Cadena ND, Vittor AY (2018) Deforestation and vector-borne disease: forest conversion favors important mosquito vectors of human pathogens. Basic Appl Ecol 26(Feb):101–110
CGIAR (2015) Impact of bean research in Rwanda and Uganda. Impact brief no. 46. Rome: CGIAR IndependentScience for Development Council, Standing Panel of Impact Assessment. https://iaes.cgiar.org/sites/default/files/pdf/SPIA_Impact-Brief-46_Jan2015.pdf
Chan K, Tusting LS, Bottomley C, Saito K, Djouaka R, Lines J (2022) Malaria transmission and prevalence in rice-growing versus non-rice-growing villages in Africa: a systematic review and meta-analysis. Lancet Planet Health 6(3):e257–e269. https://doi.org/10.1016/S2542-5196(21)00349-1
Chaves LSM, Fry J, Malik A, Geschke A, Sallum MAM, Lenzen M (2020) Global consumption and international trade in deforestation-associated commodities could influence malaria risk. Nat Commun 11(1):1–10. https://doi.org/10.1038/s41467-020-14954-1
Connor M, Cuong OQ, Demont M, Sander BO, Nelson K (2022) The influence of climate change knowledge on consumer valuation of sustainably produced rice in Vietnam. Sustain Prod Consum 31(May):1–12. https://doi.org/10.1016/j.spc.2022.01.034
Derua YA, Kweka EJ, Kisinza WN, Githeko AK, Mosha FW (2019) Bacterial larvicides used for malaria vector control in sub-Saharan Africa: review of their effectiveness and operational feasibility. Parasite Vector 12:426. https://doi.org/10.1186/s13071-019-3683-5
Elder SD, Zerriffi H, Le Billon P (2013) Is Fairtrade certification greening agricultural practices? An analysis of Fairtrade environmental standards in Rwanda. J Rural Stud 32(October):264–274. https://doi.org/10.1016/j.jrurstud.2013.07.009
Elliott LM, Daglish SL, Topp SM (2022) Health taxes on tobacco, alcohol, food and drinks in low-and middle-income countries: a scoping review of policy content, actors, process and context. Int J Health Policy Manag 11(4):414–428. https://doi.org/10.34172/ijhpm.2020.170
Estrada MA (2018) Smoking and health in the Philippines: five years after sin tax reform. CPBRD Policy Brief No. 2018–01. Congressional Policy and Budget Research Department, House of Representatives. Manila, The Philippines. https://doi.org/10.13140/RG.2.2.28499.94245
Fillinger U, Kannady K, William G, Vanek MJ, Dongus S, Nyika D, Geissbühler Y, Chaki PP, Govella NJ, Mathenge EM, Singer BH (2008) A tool box for operational mosquito larval control: preliminary results and early lessons from the Urban Malaria Control Programme in Dar es Salaam, Tanzania. Malar J 7(1):1–25. https://doi.org/10.1186/1475-2875-7-20
Fitzgerald MP, Lamberton CP, Walsh MF (2016) Will I pay for your pleasure? Consumers' perceptions of negative externalities and responses to Pigovian taxes. J Assoc Consum Res 1(3):355–377. https://doi.org/10.1086/686305
Flynn N, Kah C, Kerschbamer R (2016) Vickrey auction vs BDM: Difference in bidding behaviour and the impact of other-regarding motives. J Eur Econ Assoc 2:101–108. https://doi.org/10.1007/s40881-016-0027-5
Ghins L, Pauw K (2018) The impact of markets and policy on incentives for rice production in Rwanda. FAO Agricultural Development Economics Working Paper 18–02 (February). Available from: https://ageconsearch.umn.edu/record/288956/
Gregson N, Ferdous R (2015) Making space for ethical consumption in the South. Geoforum 67(December):244–255. https://doi.org/10.1016/j.geoforum.2015.02.009
Gunatilake H, Yang J, Pattanayak S, Choe K (2007) Good practices for estimating reliable willingness to pay values in the water and sanitation sector. ERD Technical Note Series 23. Asian Development Bank, Manila
Hangoma P, Surgey G (2019) Contradictions within the SDGs: are sin taxes for health improvement at odds with employment and economic growth in Zambia? Glob Health 15(1):1–9. https://doi.org/10.1186/s12992-019-0510-x
Harrison GW (2006) Experimental evidence on alternative environmental valuation methods. Environ Resour Econ 34(1):125–162. https://doi.org/10.1007/s10640-005-3792-9
Ingabire MC, Hakizimana E, Kateera F, Rulisa A, Rulisa S, Mutesa L (2019) Working with community malaria action teams (CMATs) contributes to malaria control. Rwanda Public Health Bull 1(1):37–39
ITC-International Trade Centre (2021) Standards Map App. ITC, Geneva. Retrieved from: https://www.standardsmap.org/
Kajale DB, Becker TC (2015) Willingness to pay for golden rice in India: a contingent valuation method analysis. J Food Prod Mark 21(4):319–336. https://doi.org/10.1080/10454446.2012.726946
Karema C, Wen S, Sidibe A, Smith JL, Gosling R, Hakizimana E, Tanner M, Noor AM, Tatarsky A (2020) History of malaria control in Rwanda: implications for future elimination in Rwanda and other malaria-endemic countries. Malar J 19(1):356. https://doi.org/10.1186/s12936-020-03407-1
Larnder-Besner M, Tremblay-Gravel J, Christians A (2020) Funding pandemic prevention: proposal for a meat and wild animal tax. Sustain 12(21):9016. https://doi.org/10.3390/su12219016

Loomis JB (1990) Comparative reliability of the dichotomous choice and open-ended contingent valuation techniques. J Environ Econ Manag 18(1):78–85. https://doi.org/10.1016/0095-0696(90)90053-2
Madaki M (2017) The effects of malaria on crop production in Yobe State, Nigeria. Int J Inf Res Rev 4(1):3525–3529
Mehrabi S, Perez-Mesa JC, Giagnocavo C (2022) The role of consumer-citizens and connectedness to nature in the sustainable transition to agroecological food systems: the mediation of innovative business models and a multi-level perspective. Agriculture 12(2):203. https://doi.org/10.3390/agriculture12020203
MALF-Ministry of Agriculture, Livestock and Fisheries, United Republic of Tanzania (2019) National Rice Development Strategy Phase II (2019–2030). Dodoma, Tanzania. https://riceforafrica.net/wp-content/uploads/2021/09/NRDS2_Tanzania_en.pdf
Mangani C, Frake AN, Chipula G, Mkwaila W, Kakota T, Mambo I, Chim'gonda J, Mathanga D, Mzilahowa T, Zulu L, Walker E (2022) Proximity of residence to irrigation determines malaria risk and Anopheles abundance at an irrigated agro-ecosystem in Malawi. Am J Trop Med Hyg 106(1):283–292. https://doi.org/10.4269/ajtmh.21-0390
Marx A, Depoorter C, Vanhaecht R (2022) Voluntary sustainability standards: state of the art and future research. Standards 2(1):14–31. https://doi.org/10.3390/standards2010002
Masimbi O, Schurer JM, Rafferty E, Ndahimana JDA, Amuguni JH (2022) A cost analysis of the diagnosis and treatment of malaria at public health facilities and communities in three districts in Rwanda. Malar J 21(1):1–13. https://doi.org/10.1186/s12936-022-04158-x
MINAGRI-Ministry of Agriculture and Animal Resources, Republic of Rwanda (2021) National Rice Development Strategy 2021–2030. Kigali, Rwanda. https://riceforafrica.net/wp-content/uploads/2021/09/rwanda_nrds2.pdf
Mulligan CB (2023) Beyond Pigou: externalities and civil society in the supply-demand framework. Public Choice. https://doi.org/10.1007/s11127-023-01064-x
Murindahabi MM, Hoseni A, Vreugdenhil LCC, van Vliet AJ, Umupfasoni J, Mutabazi A, Hakizimana E, Poortvliet PM, Mutesa L, Takken W, Koenraadt CJ (2021) Citizen science for monitoring the spatial and temporal dynamics of malaria vectors in relation to environmental risk factors in Ruhuha, Rwanda. Malar J 20(1):1–18. https://doi.org/10.1186/s12936-021-03989-4
My NH, Demont M, Van Loo EJ, de Guia A, Rutsaert P, Tuan TH, Verbeke W (2018) What is the value of sustainably-produced rice? Consumer evidence from experimental auctions in Vietnam. Food Policy 79(August):283–296. https://doi.org/10.1016/j.foodpol.2018.08.004
NISR-National Institute of Statistics of Rwanda, Republic of Rwanda (2021) Agricultural Household Survey 2020 report. Kigali, Rwanda. https://statistics.gov.rw/datasource/agricultural-household-survey-2020
Nsanzimana G (2019) Why Rwandans love Tanzanian rice despite high cost. The Chronicles, 24 April. https://www.chronicles.rw/2019/04/24/why-rwanda-loves-tanzanian-rice-despite-high-cost/
Oh J-C, Yoon S-J (2014) Theory-based approach to factors affecting ethical consumption. Int J Consum Stud 38(3):278–288. https://doi.org/10.1111/ijcs.12092
Okpiaifo G, Durand-Morat A, West GH, Nalley LL, Nayga RM Jr, Wailes EJ (2020) Consumers' preferences for sustainable rice practices in Nigeria. Glob Food Secur 24:100345. https://doi.org/10.1016/j.gfs.2019.100345
Patton MQ (2002) Qualitative research and evaluation methods, 3rd edn. Sage, Thousand Oaks
Phiri MD, McCann RS, Kabaghe AN, Van den Berg H, Malenga T, Gowelo S, Tizifa T, Takken W, van Vugt M, Phiri KS, Terlouw DJ (2021) Cost of community-led larval source management and house improvement for malaria control: a cost analysis within a cluster-randomized trial in a rural district in Malawi. Malar J 20:268. https://doi.org/10.1186/s12936-021-03800-4
Pinto LFG, Gardner T, McDermott CL, Ayub KOL (2014) Group certification supports an increase in the diversity of sustainable agriculture network–rainforest alliance certified coffee producers in Brazil. Ecol Econ 107(November):59–64. https://doi.org/10.1016/j.ecolecon.2014.08.006
Pullar J, Allen L, Townsend N, Williams J, Foster C, Roberts N, Rayner M, Mikkelsen B, Branca F, Wickramasinghe K (2018) The impact of poverty reduction and development interventions on non-communicable diseases and their behavioural risk factors in low and lower-middle income countries: a systematic review. PLoS ONE 13(2):e0193378
Rohr JR, Barrett CB, Civitello DJ, Craft ME, Delius B, DeLeo GA, Hudson PJ, Jouanard N, Nguyen KH, Ostfeld RS, Remais JV, Riveau G, Sokolow SH, Tilman D (2019) Emerging human infectious diseases and the links to global food production. Nat Sustain 2(6):445–456
Rulisa A, van Kempen L, Koch D-J (2022) When local trade-offs between SDGs turn out to be wealth-dependent: interaction between expanding rice cultivation and eradicating malaria in Rwanda. Sustainability 14(4):2100. https://doi.org/10.3390/su14042100
Rulisa A, van Kempen L, Mutesa L, Hakizimana E, Ingabire CM, Kateera F, Koenraadt CJM, van Vugt M, van den Borne B (2021) Willingness to contribute to bio-larviciding in the fight against malaria: a contingent valuation study among rice farmers in Rwanda. Int J Environ Res Public Health 18:11575. https://doi.org/10.3390/ijerph182111575
Runkle BR, Seyfferth AL, Reid MC, Limmer MA, Moreno-García B, Reavis CW, Peña J, Reba ML, Adviento-Borbe MAA, Pinson SR, Isbell C (2021) Socio-technical changes for sustainable rice production: rice husk amendment, conservation irrigation, and system changes. Front Agron 3:741557. https://doi.org/10.3389/fagro.2021.741557
Sabates-Wheeler R, Yates S, Wylde E, Gatsinzi J (2015) Challenges of measuring graduation in Rwanda. IDS Bull 46(2):103–114. https://doi.org/10.1111/1759-5436.12133
Sajise AJ, Samson JN, Quiao L, Sibal J, Raitzer DA, Harder D (2021) Contingent valuation of nonmarket benefits in project economic analysis: a guide to good practice. Manila: Asian Development Bank. https://www.adb.org/sites/default/files/publication/761816/valuation-nonmarket-benefits-project-economic-analysis-guide.pdf
Smith S, Anker R, Anker M, Prates I (2020) Anker living income reference value: rural Rwanda 2020. Global Living Wage Coalition. https://www.globallivingwage.org/wp-content/uploads/2020/08/Rural-Rwanda-LI-Reference-Value.pdf
SRP-Sustainable Rice Platform (2020) The SRP Standard for Sustainable Rice Cultivation (Version 2.1). SRP, Bangkok. Retrieved from: http://www.sustainablerice.org
UNCTAD-United Nations Conference on Trade and Development (2020) Framework for the voluntary sustainability standards assessment toolkit. https://unctad.org/system/files/official-document/ditctabinf2020d5_en.pdf

USAID-United States Agency for International Development (2022) Rwanda malaria profile. https://d1u4sg1s9ptc4z.cloudfront.net/uploads/2023/01/Rwanda-Malaria-Profile-1.pdf
USAID-United States Agency for International Development (2019) Rwanda: Malaria Operational Plan FY 2019 (President's Malaria Initiative). Penny Hill Press, Damascus
Venkatachalam L (2004) The contingent valuation method: a review. Environ Impact Assess Rev 24(1):89–124. https://doi.org/10.1016/S0195-9255(03)00138-0
Wamukui G, Shukla J, Odour J (2015) Assessment of voluntary sustainability standards implementation on the environmental performance of the tea sector in Rwanda: a comparative study of Sorwathea and Mulindi tea factories in Rwanda. Int J Bus Manag Soc Sci 6(9):126–138
Wang E, Gao Z (2017) Chinese consumer quality perception and preference of traditional sustainable rice produced by the integrated rice–fish system. Sustainability 9(12):2282. https://doi.org/10.3390/su9122282
Whittington D, Smith VK, Okorafor A, Okore A, Liu JL, McPhail A (1992) Giving respondents time to think in contingent valuation studies: a developing country application. J Environ Econ Manage 22(3):205–225. https://doi.org/10.1016/0095-0696(92)90029-V
Yang S-H, Hu W, Mupandawana M, Liu Y (2012) Consumer willingness to pay for fair trade coffee: a Chinese case study. J Agric Appl Econ 44(1):21–34. https://doi.org/10.22004/ag.econ.120449
Zhou J, Liu Q, Mao R, Yu X (2017) Habit spillovers or induced awareness: willingness to pay for eco-labels of rice in China. Food Policy 71(August):62–73. https://doi.org/10.1016/j.foodpol.2017.07.006

Publisher's Note