



Can the digital long tail effect in farmers' markets increase crop diversity on farms and in diets?

A pilot study from Costa Rica

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EXECUTIVE SUMMARY

Farmers' markets play a key role in food systems. They provide income for small-scale producers, offer consumers diverse and healthy food options, and help sustain agrobiodiversity on farms. Economic development is often thought to reduce agrobiodiversity, weakening both farm resilience and diet quality. Yet digital platform business models in advanced economies have shown that diversity can also be profitable through so-called "long tail" effects, in which niche products collectively create substantial market value.

Using a case study, we explore whether such leapfrog innovation could help prevent the loss of agrobiodiversity in modern value chains by activating a digital long tail effect within an existing farmers' market. Our research focuses on a market in Costa Rica, where sellers already offer a wide range of crops, but buyers still struggle to find certain "opportunity crops," especially tropical fruits. We piloted a digital platform over a short period and found that it was well received by users. With supportive local government policies, this model could become a viable business approach that sustains both crop diversity and rural livelihoods.

1. Introduction

Economic progress is generally expected to lead to a decline in agricultural biodiversity (Kontoleon et al. 2008). Advanced economies tend to concentrate on their own relative advantage, financialize risk management to make diversified production less relevant, move from small-scale operations to large-scale market-oriented production, and aggregate production in fewer, more standardized streams of products.

The expectation is that crops that were once locally important will be further marginalized as agriculture becomes more commercial, driven by economic development and urbanization.

These trends have potentially negative consequences for farmers with small and mid-sized farms and low-income consumers in the Global South (Vernooy 2022). Diversified farming systems can protect farmers against the risks of crop failure, providing a 'natural insurance'. In situations where access to finance is limited, this may be one of the few ways to address climate-related risks.

Difficulties in growing and marketing a diverse set of crops can limit their risk management options. On the other hand, low-income consumers depend largely on local markets for their food. Market access has an influence on diet diversity, an important indicator of food and nutrition security (Nandi et al. 2021). A low diversity of food intake is associated with low micronutrient intake (Vergar et al. 2021).

Negative trends are indeed well advanced in some contexts. Global trade in crops is diversifying in terms of the average number of crops traded, yet pushes local crops to the margins. Also, diets tend to reduce in diversity, as previously locally common crops, such as nutrient-dense local leafy vegetables, fall out of the diet. These trends tend to reinforce themselves, as less produced crops will receive less attention from research and development, which will exclude them increasingly from high-production systems (Manners and Van Etten 2018).

Many efforts have tried to halt this trend and promote so-called opportunity crops, also known as neglected and underutilized crop species (NUS). Often, investments are directed at taking away barriers to their production through breeding or agronomic research. Other efforts are directed at developing formalized value chains that insert these products into the formal economy. For example, value chain development has been proposed as a major effort under Vision for Adapted Crops & Soils (VACS), a major investment in opportunity crops (Levine et al. 2024). Often, however, these efforts have a narrow effect on a small group of crops or crop varieties, as formal value chains for these crops are subject to the same constraints as for more widely grown crops. Building new value chains takes large investments and is often a barrier to diversification (Weituschat et al. 2023).

Interestingly, the expectation that modernization leads to less diversity does not always hold true. For certain groups of products, modern economies are now showing a trend in the opposite direction. Some of this is due to the digitalization of the economy. As information costs reduce, it becomes easier to coordinate a diverse supply with demand for niche products. For example, digital platforms sell books that brick-and-mortar stores do not offer. It is not economically viable to dedicate shelf space to books that sell only a few copies per year, but many books can be held in cheap central storage or even printed on demand. Music streaming services have made some lesser-known music known to a global audience and have fostered subcultures around specific genres that did not even exist before. The sharing economy makes it possible to

offer boutique products and services. This effect is called the ‘long tail’, as described by Anderson (2014).

In a way, digital platforms contradict dominant trends in the economy and adopt features of more traditional ways of economic organizing. Quality control is often not formalized but managed through user feedback, which is reflected in the reputation of the sellers and buyers. On some digital platforms, sellers provide highly personalized products or services. Some digital platforms not only facilitate transactions but also foster relations of community, identity, and trust. Some peer-to-peer sharing platforms resemble gift economies that work through reciprocity rather than commercial transactions. Gig platforms generate a new informal economy.

Digital platform business models generate a profound challenge to mainstream economic thinking. Whether the emerging digital economy has a net positive or negative effect will depend on many factors, including how platforms will be designed and governed. In this paper, we explore the potential positive effect of such a digital platform on mobilizing crop diversity in a local farmers’ market. We investigate the supply and demand of opportunity crops, which are those crops which are neglected and underutilized given the potential contribution they can make to livelihoods and nutrition.

2. Study background

2.1 Opportunity crops: neglect, opportunities and marketing constraints

As Padulosi and Hoeschle-Zeledon (2004) pointed out, the reasons for the neglect of different crops are complex and derive from a variety of agronomic, economic, and social factors. Galluzi and Noriega (2014) determined the magnitude of a crop’s unrealized potential by defining six dimensions of neglect: low research efforts, low representation in ex situ collections, low representation in *in situ* collections, low efforts in germplasm characterization, limited knowledge of production levels, and lack of plant breeding efforts.

The benefits commonly associated with opportunity crops go beyond the mere potential to diversify agricultural landscapes and systems. Some are significantly contributing to food security in developing countries where they are important both in terms of consumption and local production (Williams & Haq, 2002). Also, many underutilized vegetables are far superior to equivalent widely grown crops in terms of nutritional value (Ebert, 2014). Hence, they are seen as a promising way to fight hunger and

malnutrition (IPGRI, 2002). Furthermore, their production is associated with poverty reduction since they can improve livelihoods and create income in rural areas (Gotor et al., 2013). Since those under-exploited crops are usually found in traditional or indigenous farming systems, especially small farmers are supposed to benefit from their cultivation. In many parts of the world certain opportunity crops are tightly connected to cultural identity, which is why promotion of those crops can help to conserve traditional knowledge and values (Padulosi et al., 2013). Other authors point out the role of opportunity crops in the adaptation to climate change and the mitigation of its effects (Bowe, 2007; Padulosi et al., 2009; Padulosi et al., 2014).

Low market activity seems to be a crucial factor that limits the full realization of a crop's potential (Gruère et al., 2006). The lack of economic incentives and low market value, high transaction costs for market access or limited marketability impedes further crop cultivation and consumption. In Benin, for example, 98% of the consulted farmers reported that the lack of organized markets represents a reason for neglect of opportunity crops (Dansi et al., 2012).

2.2 Role of farmers' markets

Farmers' retail markets that are administered by the municipal government, take place in defined indoor or outdoor places and are mainly supplied by producers, and some intermediaries (Reyes et al. 2016). An important feature of these markets is the absence of food safety standards and demands for product uniformity (CIAT, 2010). Even though it is difficult to obtain reliable data that quantifies the market share of these marketplaces in comparison to other sales channels, there is no doubt that they remain of great importance in Latin America.

Little attention has been paid to how farmers' markets contribute to livelihoods, food security and nutrition (Grace et al., 2014). In Honduras and Nicaragua, traditional markets were found to cater especially to the needs of low-income households since they carry benefits for producers and consumers with limited economic resources (Reyes et al., 2016). However, in Costa Rica, where average income levels are higher, local farmers' markets are also vibrant and present throughout the country. An investigation on food consumption in Costa Rica revealed that 22% of the surveyed households prefer local farmers' markets in order to acquire fruits and vegetables (PIMA, 2012). Also, traditional markets enable producers to offer small quantities of seasonal crop products

catering to their customers' preferences without the constraints of product standardization or reaching a minimum volume required by industry or supermarket supply chains. Therefore, the farmers' market would promote the diversification of diets and preservation of agrobiodiversity.

In Costa Rica, the farmers' markets (*ferias del agricultor*) that are now present in the country were established in the 1970s by a farmer-initiated effort as agroindustrial quality standards inhibited a large share of their produce from being sold. Furthermore, farmers' markets fulfilled the need for fair distribution channels. Through direct marketing, producers became less dependent on the involvement of intermediaries and thus gained a higher marginal profit (Díaz-Knauf et al., 1992). What started as a small movement quickly became a large phenomenon. At present, there are around 80 farmer markets in Costa Rica under the jurisdiction of the National Production Council (CNP). Regulations include aspects on food safety as well as the structural organization of the market. The regulation explicitly prohibits the presence of intermediaries (CNP, 2006).

2.3 Digital platforms

Two-sided digital platforms connect two groups that depend on each other—typically producers and consumers—without producing goods or services themselves. Their purpose is to make exchange more efficient. The more participants join on one side, the more attractive the platform becomes for the other. This is the so-called network effect (Parker et al., 2016).

Digital platforms can create what has been called the long tail effect (Anderson, 2006). Conventional markets focus on popular products that sell in large quantities. Online platforms, by contrast, can make niche or low-volume products visible and accessible (Figure 1). With lower costs for storage, search, and distribution, even small producers can find a modest but steady demand. In this way, platforms can increase the diversity of what is offered and consumed.

There are, however, risks. Platforms tend to concentrate control over data and transactions, which can lead to dependency or monopolistic power. Algorithms can at the same time make some items invisible, favouring products that already attract attention or are promoted through payment. Income and visibility are rarely distributed evenly. As a result, platforms can widen access and variety, but they can also reproduce existing inequalities if left unchecked. Here, we test a prototype of a digital platform, not engaging in wider governance aspects. However, by engaging in a public market, these aspects need to be addressed to ensure that its public character is not undermined.

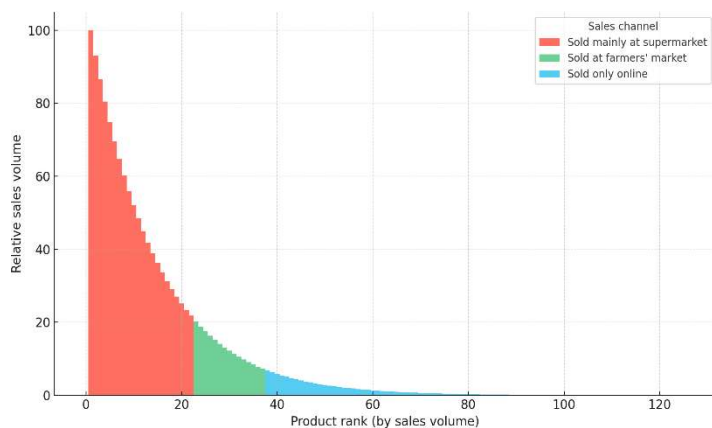


Figure 1. A hypothetical example of how the long tail effect can support diversity. Online platforms often sell items that normal outlets cannot afford to offer, due to their low sales volumes.

Another aspect is the character of farming and commerce. Zárate Vásquez and Delborne (2025) describe an effort to design a digital platform to augment diverse Andean potato sales. The designers discovered that Andean potato farmers are not only motivated by economic factors in potato diversity use but also to conserve their particular way of living. They emphasize that the design of such a platform should avoid inappropriate cultural assumptions about data ownership, economic relationships, and the limitations of current commercialization efforts.

3. Materials and methods

3.1 Study area

As indicated above, traditional farmers' markets play an important role for fresh fruit and vegetable consumption in developing countries of Latin America like Costa Rica. We chose to study the well-established farmers' market in Turrialba, Costa Rica. The farmers' market in Turrialba is one of the oldest in the country and has attracted vendors and consumers for more than 50 years. Since farmers' markets have generally been neglected by research and investigations, little is known about the crop diversity that they supply.

The farmers' market at the study site Turrialba is not part of the licensed *ferias del agricultor* but is similar in scope. The market was one of the earliest to emerge in the 1970s and kept its autonomy since then. The farmers' market in Turrialba is

under the category of Municipal Free Market. It is administered by a board representing local institutions and stakeholders, an arrangement that is somewhat different from the markets that fall under the Ministry of Agriculture and Livestock (MAG). Even though the aim of the farmers' market in Turrialba is to promote local producers, the resale of products by intermediaries is allowed in some cases. Generally, the requirements for participation are more relaxed compared to the licensed *ferias del agricultor*. In Turrialba, each producer, manufacturer or member of a cooperative is allowed to offer his products at the farmers' market as long as there are free stands available. Due to space limitations, the maximum number of stands is usually set around 130. Additionally, each vendor has to pay a fee of 1000 colones (1.77 US \$) to the municipality, which is collected in the morning of each market day. Since its origin in 1970, the farmers' market in Turrialba has taken place along the old railroad tracks in the centre of town. The vendor stands form two long lines, each of them approximately 80 m long.

3.2 Data collection

Information about the market history and structure was provided through personal communication by the market administrator of the municipality in Turrialba. In order to obtain information about the products on offer, we conducted semi-structured interviews with all 98 market vendors that sold fresh produce on four weekends (eight market days) between August and September 2016. The vendors named the products they regularly offer at their stand and also indicated if they produced them on their own or if they bought them from another producer (resale). Also, vendors were asked to name the crops present on their farms which correspond to the concept of opportunity crop, regardless of whether they offered them on the market or not, and to indicate possible market barriers.

The current market limitations of opportunity crops were investigated by focusing on a subset of crops, which are not extremely rare but might have potential growth. We picked this subset of thirteen with the following criteria. We focused on crops that are relatively neglected, using the list provided by Galluzzi & Noriega (2014). Only unprocessed crops were included, not processed foods. We excluded crops not native to the American continent from our definition of opportunity crops in this study. We included eleven crops that at least 5% of the producers grow on their own farm, when less than 60% of them sell it in the market. These crops could easily expand in market supply. We also included two crops grown by less than 5% of the producers, if more than 60% of those who produce it sell it on the market. These crops could potentially be grown more widely. Rare, underutilized

varieties of crops (e.g. *Musa* spp.) were not included as opportunity crops but could be considered in future studies that focus on varietal diversity.

We selected 25 survey participants by using a random sampling method among the market visitors that have been shopping at the farmers' market in Turrialba on two weekends (four market days) at the end of September 2016. We presented pictures of the 13 selected crop products to these market visitors, testing their visual recognition of the products. If they identified the crop species correctly, they were asked to indicate whether they usually buy it or not. If they recognized the crop species but did not buy this product, they were asked for their reasons for not buying it.

3.3 Digital market platform pilot

To test if the digital long tail effect can be used to promote crop diversity in farmers' markets, we ran a pilot digital market. The idea was to make local producers more visible in a rapidly digitalizing market context, while maintaining the familiar dynamics of traditional agricultural fairs. The design had members with participant knowledge of farmers' markets in Costa Rica and used ethnographic methods to gain further understanding of the perspectives of different market participants.

The prototype the team developed integrates well-known concepts, such as stalls, producers, and consumers, into a digital format that fosters interaction, communication, and logistical coordination. The platform operated with the principle that markets should benefit both parties. Farmers were empowered to set prices they considered fair, while consumers could compare prices and quality, promoting transparency and autonomy on both sides. Direct communication between producers and consumers was encouraged, allowing for negotiations, special requests, and feedback. This interaction contributed to building confidence among farmers in using mobile devices and digital tools, often perceived as a barrier to entry.

As we wanted to test the potential of this platform for the recovery and promotion of underutilized crops, these products were included in the offer but not promoted in a special way within the digital platform itself. However, the communication around the platform did mention this objective. The platform was branded as "Tacaco" a name that derives from an endemic Costa Rican fruit, an opportunity crop that symbolizes the goal of cultural and dietary preservation (Figure 2).

The platform was developed in the widely used WordPress environment. It allows for the administration of user registration, weekly sales management, technical support, and report generation. This technical setup ensures flexibility and accessibility for users with different levels of digital experience.

Producers were trained by showing them how to create their own virtual stalls, where they can describe their production practices and offer the products available on a weekly basis. The platform includes a learning section aimed at both farmers and consumers. This section provides guidance on the effective use of the platform and general information to support digital literacy and marketing skills. In its implementation, the team promoted environmental awareness, introducing measures to reduce plastic use in product delivery. Producers were encouraged to minimize packaging and to use reusable wooden boxes.



Figure 2. The logo of Tacaco. It features a stylized drawing of the fruit of tacaco, *Sechium tacaco*, an iconic locally endemic crop.

Tacaco was co-developed in several iterations from prototype to production, combining technological innovation with social participation and local governance considerations. The development and implementation of Tacaco were made possible through the collaboration of several institutions and local stakeholders. MrBot Software Solutions led the platform's design, technical development, and operational management, ensuring usability, maintenance, and continuous improvement. The Alliance of Bioversity International and CIAT contributed through technical guidance and coordination, supporting the integration of digital tools into local food system initiatives. The Ministry of Agriculture and Livestock (MAG) provided institutional support and alignment with national agricultural policies promoting market access for smallholders. The Municipality of Turrialba facilitated the connection with local actors and ensured that the platform was adapted to the needs of the community. Producers and sellers of

the Turrialba market played a central role in testing and adopting the platform, shaping its functions through direct feedback and participation.

The Tacaco digital platform was publicized through different media channels, including a Facebook page. The news was picked up by national public television (Céspedes 2020; Figure 3).

The platform was deployed online from July 20, 2020 to November 18, 2020. During this period, 40 registered buyers used the service. This took place during the COVID-19 epidemic, which may have encouraged users to explore this purchase channel. To evaluate the performance of the digital platform, we gathered data from the platform itself, as well as qualitative impressions from users, including both sellers and buyers.



Figure 3. National television covered the news of the launch of the platform, demonstrating its appeal.

4. Results

4.1 Description of the market

During the time of the investigation there were 119 distinct stands at the farmers' market. Fourteen stands sold processed agricultural products such as meat, cheese, ceviche, cooked palm fruits or ornamental flowers, as well as arts and crafts. These stands were not included in the study. The remaining 105 stands offered fruit or vegetables for sale and were considered in the survey. Out of those, 44 were dedicated to vegetables with very few other products, whereas 38 stands sold a mix of different types of fresh produce, and 23 stands were dedicated mainly to fruits. We were able to interview 98 vendors. They obtained their products from

different sources. There were 43 producers who exclusively offered their own produce, 44 producers who offered their own products as well as resold products purchased from others, and 11 intermediaries which only re-sold produce grown by others.

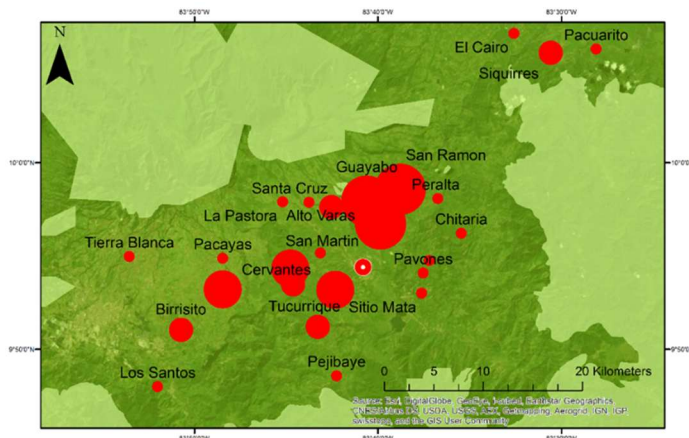


Figure 4. Origin of producers selling at Turrialba market. Larger circles indicate a larger number of producers. The Turrialba market itself is indicated with a white dot in the red circle.

Most of the vendors said that their household income depends entirely on agriculture and that their revenue comes entirely from market sales in Turrialba. Only 30 out of 105 vendors (29%) used additional sale channels such as sodas (low-cost local restaurants), neighbourhood shops or wholesale markets to complement their sales at the farmers' market.

As shown in Figure 4, all producer farms were located within a 30 km radius (as the crow flies) from the town of Turrialba. Most of the farms that cater to the farmers' market in Turrialba were located within the province of Cartago. Only a few producers came from the neighbouring province of Limón. Additionally, some vendors acquired their products at the wholesale markets in the provinces of Cartago, Alajuela or San José (not shown in Figure 4).

The sellers on the market cover most of the agricultural communities in the area, as cultivation of land is prohibited within the protected areas of the Turrialba Volcano National Park in the north and the Barbilla National Park in the east. Most of the producers came from the villages of Guayabo and San Ramón in the area north-east of Turrialba. Market sellers' farms were small. Farm size was an average of 3.04 hectares, varying between 0.1 and 21.0 ha. Resellers also

obtained products at regional markets outside the area shown on the map.



Figure 5. Impression of the Turrialba market

4.2 Crop species offered

The total number of 107 crops were on offer at the market during the year. This number of crops also includes plant products that only get sold in certain months due to seasonal availability. Most of them were categorized as fruits and vegetables, the rest of them were mainly herbs, spices or tubers. Most of those crops were produced locally and only eleven of them came exclusively from outside the region or country (garlic, plum, chickpea, kiwi, peach, cantaloupe, watermelon, nectarine, pear, tamarind and grape). Therefore, the market offers a remarkable diversity of crop species, mostly grown within a short distance from the market.

Not all the diversity present on farms reaches the market. The original producers named fourteen different crops that they grow on their farms for exclusive use within the family but never bring to the market. We classified nine of these crops as opportunity crops (Table 1). Most

of those unsold crops were medicinal plants. They were exclusively used for their own consumption.

Following the definition mentioned above, 45 plants were classified as opportunity crops. This number includes the crops sold at the market as well as the ones cultivated only at vendors' farms for home consumption. Roughly half of the 45 identified opportunity crops were fruits, 8 were medicinal plants, and only 6 were vegetables and 4 that corresponded to the remaining categories (roots/tubers, herbs/spices).

When vendors were asked to name the plants on their farms they considered to be underutilized, they mentioned a total of 58 different plant species. Opinions varied a lot from one vendor to the other and many plants have been considered as underutilized by one farmer whereas most of them thought otherwise. All opportunity crops were recognized as underutilized by at least one farmer, except the vegetable chayote. Chayote was also the most offered crop among the opportunity crops. This is an opportunity crop globally, but which is a successful export crop, grown in the nearby Ujarrás valley. Other commonly mentioned crops were the tuber crop *malanga*, the fruit *cas*, and the herb *culantro coyote*.

The cultivation of opportunity crops was common among the surveyed vendors. From the 87 producers, only 13 did not cultivate any opportunity crop on their farm. Most of the producers reported to have at least one or two different opportunity crops at their farm and some of them even specialized in their cultivation and one farmer reported to grow up to 15 different ones.

In 65 % of the cases, if a cultivated opportunity crop was present on the farm it was offered for sale at the market. This shows that there is a certain volume of opportunity crop production that remains behind on the farms. For comparison, the average market offers of crops outside of the category of opportunity crops was 86 %. In 98 % of the cases, root and tuber opportunity crops present on farms were taken to the market. For medicinal opportunity crops this was only 2.6% of all cases (see Table 1).

Table 1. Crops at the market in Turrialba which are considered ‘opportunity crops’, following Galluzzi & Noriega (2014). Survey results of 98 vendors. In bold the crops selected for the buyers’ study.

Spanish name (Costa Rica)	Scientific name	Native to the Americas	Sellers who grow it but do not sell it	Sellers who sell it at the market
Azul de mata	<i>Baptisia tictoria</i>	Yes	1	0
Calabaza cintura	<i>Cucurbita spp</i>	Yes	1	0
Castaña	<i>Artocarpus camansi</i>	No	1	0
Gavilana	<i>Neurolaena lobata</i>	No	2	0
Hombre grande	<i>Quassia amara</i>	Yes	1	0
Juanilama	<i>Lippia alba</i>	Yes	4	0
Nispero	<i>Eriobotrya japonica</i>	No	1	0
Noni	<i>Morinda citrifolia</i>	No	1	0
Rosa de Jamaica	<i>Hibiscus sabdariffa</i>	No	1	0
Ruda	<i>Ruta graveolens</i>	No	3	0
Zacate de limón	<i>Cymbopogon citratus</i>	No	1	0
Mozote	<i>Triunfetta lappula</i>	Yes	15	4
Mamey	<i>Mammea americana</i>	Yes	1	1
Carambola	<i>Averrhoa carambola</i>	No	4	5
Nance	<i>Byrsonima crassifolia</i>	Yes	4	5
Naranjilla	<i>Solanum quitoense</i>	Yes	3	4
Cúrcuma	<i>Curcuma longa</i>	No	1	2
Caiba	<i>Cyclanthera pedata</i>	Yes	1	3
Tacaco	<i>Sechium tacaco</i>	Yes	1	3
Guayaba	<i>Psidium guajava</i>	Yes	2	8
Caimito	<i>Chrysophyllum cainito</i>	Yes	1	4
Pejibaye	<i>Bactris gasipaes</i>	Yes	1	5
Coyote	<i>Eryngium foetidum</i>	Yes	2	11
Guanabana	<i>Annona muricata</i>	Yes	1	7
Mamón chino	<i>Nephelium lappaceum</i>	No	1	8
Cas	<i>Psidium friedrichsthalium</i>	Yes	1	13
Malanga	<i>Xanthosoma sagittifolium</i>	Yes	1	15
Chayote	<i>Sechium edule</i>	Yes	0	33
Fruta de pan	<i>Artocarpus altilis</i>	Yes	0	8
Tiquisque	<i>Xanthosoma violaceum.</i>	Yes	0	5
Yuplón	<i>Spondias dulcis</i>	No	0	5
Chamol	<i>Colocasia esculenta</i>	No	0	4
Manzana de agua	<i>Syzygium malaccense</i>	No	0	4
Arazá	<i>Eugenia stipitata</i>	Yes	0	3
Jocote	<i>Spondias purpurea</i>	Yes	0	3
Anona	<i>Annona cherimoya</i>	Yes	0	2
Arracache	<i>Arracacia xanthorrhiza</i>	Yes	0	2
Hoja tamalera	Various species	Yes	0	2
Uchuva	<i>Physalis peruviana</i>	Yes	0	2
Achiote	<i>Bixa orellana</i>	Yes	0	1
Cocona	<i>Solanum sessiliflorum</i>	Yes	0	1
Flor itabo	<i>Yucca guatemalensis</i>	Yes	0	1
Granadilla	<i>Passiflora ligularis</i>	Yes	0	1
Mangostan	<i>Garcinia mangostana</i>	No	0	1
Zapote colombiano	<i>Quararibea cordata</i>	Yes	0	1

Table 2. Crops at the market in Turrialba which are not considered ‘opportunity crops’, following Galluzzi & Noriega (2014). Survey results of 98 vendors.

Spanish name (Costa Rica)	Sellers who grow it but do not sell it	Sellers who sell it at the market	Spanish name (Costa Rica)	Sellers who grow it but do not sell it	Sellers who sell it at the market
Cola de caballo	1	0	Cebollino	0	12
Toronja	1	0	Mango	0	12
Tucuico	1	0	Camote	0	11
Menta	4	1	Palmito	0	10
Romero	4	1	Piña	0	10
Sábila	3	1	Guineo negro	0	9
Yerba buena	3	1	Rábano	0	9
Jengibre	2	1	Sandía	0	9
Oregano	4	4	Coliflor	0	8
Albahaca	1	2	Chile panameño	0	6
Limón mesíno	4	14	Espinaca	0	6
Coco	1	5	Manzana	0	6
Naranja	4	25	Aguacate	0	5
Limón mandarino	5	34	Maracuja	0	5
Mandarina	2	16	Melon	0	5
Culantro	1	26	Mora	0	5
Yuca	1	29	Alberjones	0	4
Banano	1	30	Choy	0	4
Vainica	1	40	Berro	0	3
Plátano	0	41	Cirucla	0	3
Chile dulce	0	36	Kale	0	3
Pepino	0	35	Mostaza	0	3
Tomate	0	30	Pera	0	3
Ayote	0	24	Tamarindo	0	3
Frijol	0	23	Uva	0	3
Papaya	0	23	Ajillo	0	2
Apio	0	21	Arugula	0	2
Elote	0	21	Berenjena	0	2
Cebolla	0	20	Kiwi	0	2
Papa	0	20	Melocoton	0	2
Zanahoria	0	20	Nectarina	0	2
Lechuga	0	19	Eneldo	0	1
Repollo	0	18	Estragon	0	1
Tomillo	0	18	Fresa	0	1
Remolacha	0	16	Garbanzos	0	1
Brócoli	0	14	Hinojo	0	1
Zapallo	0	13	Perejil	0	1
Ajo	0	12	Puerro	0	1

In Table 1, there is a large group of fruit crops that is in between these two extremes, in which sales could probably increase. Fruit trees are present on many farms, but their harvest is not always sold. Examples are *carambola* and *nance* which producers reported for 9 different farms but only 5 of these vendors offered them for sale, in both cases. When farmers were asked why they did not bring those products to the farmers' market, they mentioned low prices, low demand and short shelf-life of those fruits. For some opportunity crops they indicated that they grow wild on their farm as part of the natural vegetation and did not require any cultivation effort. Thus, the farmers occasionally used them for home consumption but had no specific interest in selling them.

In only 15 % of all market offers involving an opportunity crop, it was resold by a vendor that did not originally produce it. For comparison, other crops were resold at nearly double this rate, at 28.5 %. This was reflected in the distribution of opportunity crops among different types of sellers. While original producers offered an average of 2.3 opportunity crops at their stand, intermediaries were found to offer only 1.2 on average. Between those two extremes were those vendors with a farm that produced crops but also occasionally resold produce from other sources, with an average of 1.7 opportunity crops.

Those of the vendors who sold opportunity crops on a regular basis stated that they had frequent customers who came every week and asked specifically for those products. Generally, most of the vendors were very receptive to the idea of developing a strategy for enhanced opportunity crop awareness and consumption. They blamed the monotonous diet of most market visitors for the low demand of opportunity crops and stated that traditional crops would slowly disappear.

4.3 Buyer perception of opportunity crops

On average, the market visitors were able to identify on average 10.5 of the 13 high-potential opportunity crops correctly. They purchased on average 6.1 of them on a regular basis, less than half. There were large differences in popularity among the opportunity crops when their degree of recognition by the consumer was compared to the willingness to purchase them (Table 2). Products such as *cocona*, *flor itabo* and *uchuva* were the ones least recognized by the market consumers. Also,

customers who knew these crops showed a low willingness to buy those products. The other opportunity crops were better known but not always more frequently bought by the consumers. Even though both *jocote* and *tacaco* were very well known, *jocote* was frequently bought by 92 % of the surveyed consumers whereas only 25 % bought *tacaco* on a regular basis.

The reasons that people stated for not purchasing a specific crop varied noticeably among the different crops (Table 3). The most cited reasons were the continuous availability of the crops in the market. This may include the search costs, because many products were found to be present in the market but only with a small number of sellers.

When market visitors were asked what would increase their consumption of opportunity crops, 16 people said they would buy more of them if more information about their nutritional properties or preparation methods was readily available. Furthermore, a common statement was that vendors need to offer those opportunity crops more frequently on a regular basis in order to make them more present in people's minds and to lead them the way back into the eating habits of the local population. Most respondents reacted very positively and showed high interest in the topic, stating that they remembered consuming several of these crops on a regular basis in their childhood. The high-potential opportunity crops were generally associated with family traditions and a healthy diet.

Table 3. Consumers' knowledge and purchasing behaviour of 13 selected crops available at the market in Turrialba.

Common name	Scientific name	Food category	Buyers who recognize visually (n=25)	Buyers who regularly purchase (n=25)	Top cited reasons for not purchasing the crop
Anona	<i>Annona cherimoya</i>	Fruit	25	15	Substituted with <i>guanábana</i> (<i>Annona muricata</i>), too expensive.
Arazá	<i>Eugenia stipitata</i>	Fruit	22	10	Obtainable for free, high preparation effort.
Arracache	<i>Arracacia xanthorrhiza</i>	Tuber	22	11	Low offer, high preparation effort, missing knowledge, obtainable for free.
Caiba	<i>Cyclanthera pedata</i>	Vegetable	25	13	Obtainable from other sources, high preparation effort, substitutable with bell peppers, lack of knowledge.
Cocona	<i>Solanum sessiliflorum</i>	Fruit	7	1	Low offer.
Flor itabo	<i>Yucca guatemalensis</i>	Vegetable	8	2	Missing knowledge, low offer.
Granadilla	<i>Passiflora ligularis</i>	Fruit	25	21	No consumption habit, obtainable from other sources.
Jocote	<i>Spondias purpurea</i>	Fruit	25	23	Taste.
Nance	<i>Byrsonima crassifolia</i>	Fruit	25	19	Obtainable from other sources.
Naranjilla	<i>Solanum quitoense</i>	Fruit	24	16	Obtainable from other sources, low offer.
Tacaco	<i>Sechium tacaco</i>	Vegetable	24	6	Low offer, high preparation effort, substitutable with other crops, taste.
Uchuva	<i>Physalis peruviana</i>	Fruit	10	6	Missing habit, lack of knowledge.
Zapote colombiano	<i>Quararibea cordata</i>	Fruit	20	9	Low offer.

4.4. Tacaco pilot

The Tacaco pilot was able to sign up 38 vendors in the Turrialba market. These vendors agreed to have a personal profile and their products on a selling platform and to receive training. Through the digital platform they offered their products and indicated the prices of their products and subsequently received orders from clients. The Tacaco team collected the items from the sellers, prepared packages and arranged pickup by clients on the market. The effort was not announced aggressively, to keep the pilot manageable. In total, 40 buyers registered.

The pilot ran for 18 weeks. Over this period, the platform registered 168 buyer transactions, worth a total of 4,092 US dollars, on average 24.39 US per buyer transaction. Each transaction included items from 9.3 different sellers on average. Therefore, the platform considerably reduced the effort that buyers need to spend on searching for sellers. Many buyers were middle-class consumers with limited time available for shopping on the market due to work obligations.

An important question is whether this reduction in search costs increased diversity in purchases. Qualitative feedback suggests that buyers appreciated the ease of finding products that they were not always aware of. Overall, the diversity in the transactions was high. Over the whole period, each buyer bought 29 different types of products on average. In each transaction, buyers purchased 16.9 different types of items. Overall, transactions included 85 out of the 107 crops at the market. These items included 19 opportunity crops. In total, 294 sales of opportunity crops were made, out of a total 2,839 sales of different types of items, more than 10% of the total. The platform did not expand the range of crops available in the market, but sales included several opportunity crops that are usually offered by only a subset of the sellers who grow them on their farms. These crops included *pejibaye*, *malanga*, *cas*, *guayaba*, *caiba*, *mamón chino*, *guanábana* and *tacaco*. Also, sales included crops that buyers found difficult to source, including *tacaco*, *zapote colombiano* and *uchuva*, the last of which is still relatively unfamiliar to the average buyer. Based on these insights, we conclude that the Tacaco platform can have a positive impact on the sales of opportunity crops.

The platform was received in a positive way by the producers who signed up. Sellers expressed themselves positively about the visibility they obtained through the platform for their farms and products. In our interactions with them, users expressed satisfaction with the platform as a positive space for seller-buyer interactions. A telling observation was that sellers made small gifts of certain products to buyers, enticing them to try certain products, going beyond a purely transactional attitude. This was also done on the physical market. Sellers perceived the platform as a complementary channel to establish new relationships with buyers. All in all, this provides evidence that the virtual market space does not contradict the social logic of the farmers' market, but functions as a virtual augmentation of this social space. This was an intended feature of the platform.

A calculation of costs and profits shows that with some improvements in efficiency the platform could become a modest yet profitable business (data not shown). This would require that several markets are served on different days during the week. Promoting the effort and training sellers to manage their virtual market stand requires an initial investment, however. Government actors showed interest in the project and supported its promotion. The effort is well aligned with government policies in Costa Rica, which favour farmers' markets. Scaling it would require a more systematic investment, however.

Additional benefits of the platform would be that it generates high-quality local jobs in logistics, digital technology, communication and marketing. Also, if sales increase how much is spent on local products rather than products imported by supermarket chains, this will stimulate the local economy, with a potential multiplier effect. A stronger local market could help to boost the local economy and create more opportunities for young people. Since the pilot, the platform has attracted the attention of other local authorities in Costa Rica and an effort to start running the platform at a major market is underway.

Table 4. Opportunity crops sold during the pilot of the Tacaco digital platform.

Common name	Number of transactions
Ayote	55
Pejibaye	42
Chayote	33
Malanga	19
Cas	18
Guayaba	18
Jocote	18
Caiba	17
Mamón chino	17
Tiquisque	13
Yuplón	13
Mangostán	6
Uchuva	6
Fruta de pan	5
Guanábana	5
Anona	3
Granadilla	3
Tacaco	2
Zapote colombiano	1

5. Discussion and conclusions

The local market in Turrialba is served mainly by small-scale producers who sell their own fresh produce and come from the region within a radius of 30 km. Therefore, it makes an important contribution to the local economy. It offers a high amount of crop diversity. Among the 107 crops present at the market, 45 corresponded to the definition of opportunity crop species used in this study. Most opportunity crops were fruits. This finding goes hand in hand with continental analysis of Galluzi & Noriega (2014) which also reports fruits to be the most common category of opportunity crops found in the Americas. Another important category was medicinal plants, herbs and spices.

Barriers to the increased use of opportunity crops are varied and seldom related to production, but rather to matching supply and demand, and awareness of potential buyers of the crops, their characteristics, preparation mode, and benefits. There was a group of

crops that were not always taken to the market and that consumers often found difficult to find. This is why a digital platform that links producers and consumers, enhancing the function of the local market, can be expected to support the expanded use of local crop diversity. Also, farmers' markets proved to be a place where agrobiodiversity use can be characterized efficiently in a very short period of time. This opens the perspective of cost-effective frequent monitoring of agrobiodiversity using digital media.

The Tacaco platform was received well locally, both by market participants and the local authorities. It showed that an impressive amount of diversity can be mobilized in a short period by enhancing the market with a digital platform. An important aspect of the platform was that its design augmented the current marketing channels by enhancing the existing market space, rather than trying to displace it. Sales included a substantial share of opportunity crops, including those that are not always taken from the farm to the market. It also provides a platform to promote specific opportunity crops in an even more intentional way, through sales promotion, information about culinary preparation or specific uses of the crops or eventually promoting their wider cultivation as demand grows. Also, the platform could help to get insights into buyers' expectations and offer pre-processed crop products that are otherwise perceived to be too perishable or demanding in terms of preparation. The platform addresses an important limitation of local markets, which is related to search costs for diverse products. The pilot shows that investments in digital market platforms can enhance the function of local markets and match supply and demand. This could set in motion the long tail effect for local crops, supporting their diversity in a modernizing economy. Through its specific design, it can also enhance seller-buyer relationships, beyond purely commercial interactions. Relation building and recognition were an important factor in users' perception of the platform (cf. Zárate Vásquez and Delborne 2025).

Scaling digital platforms and realizing the long tail effect would require a larger investment. The study demonstrates, however, that digital transformation can support market development and agrobiodiversity safeguarding in the context of highly diverse food economies. This could mean that these economies do not need to go through the trajectory of the Global North, wait for supermarketization and then move back to farmers' markets. They could leapfrog to a digitally-enabled, diverse food market.

An inherent limitation of our study was that it focused on a single market during a limited period of time. We have shown

that a market survey can provide relevant information with a relatively modest effort, as surveys of a large number of market participants can be completed in a short period of time. One aspect that would require a more detailed investigation is the social dynamics around the virtual market space and whether it truly enhances seller-buyer relationships or runs the risk of displacing personal on-site interactions in the long term. Comparative studies with other markets could reveal differences, similarities, and interactions between markets. Little is known about differences in market administration and their effects on market dynamics. Markets interact with each other as farmers visit different markets for retail, and some buy at some markets and sell at other markets. Studying markets over a longer period of time could provide insights on seasonal offer and purchasing behaviour. Finally, we have focused mainly on the diversity of products flowing through the market but not established its causal effect on farmers' incomes or the diversity of diets of consumers. Farmers' markets are crucial, information-dense spaces where many decisions are taken that affect the entire food system and therefore merit further study.

The Costa Rican markets and the pilot in Turrialba offer several lessons. The country was aware of the benefits of farmers' markets as it turned into a middle-income economy and prepared progressive legislation to support these markets. This was visionary, and the markets persisted despite the tendency of supermarketisation. A digital platform like Tacaco can form a good basis to adapt and enhance these markets to new economic conditions and sustain them as they make a viable contribution to the rural economy. Literacy rates are relatively high in Costa Rica, but these aspects of the Tacaco prototype can be adapted to different situations. Artificial intelligence makes it possible to use voice-based interaction, which could lower barriers for low-literacy users. Also, the governance of digital platforms should be defined in a way to ensure that private and public benefits are balanced, and cultural aspects are respected (cf. Zárate Vásquez and Delborne 2025). The design of the Tacaco platform benefitted from the team's intimate knowledge of agricultural retail markets in Costa Rica and extensive interviewing of buyers and sellers. Designing similar platforms for other contexts will require a systematic approach to contextualisation, which could benefit from the human-centred design

approach (Müller et al. 2024).

We see two main challenges. Developing digital platforms that support farmers' markets would require a change in mentality. Local and national governments and other actors often think in negative terms about 'informality' (Vorley 2023). However, informal markets supply the bulk of the food in the Global South in a relatively efficient way. Their positive features, such as their low thresholds to access for producers, their resilience, and their ability to supply affordable food, should be maintained. Our pilot suggests that instead of applying the principles of vertical integration of value chains, food markets could benefit from recent thinking about digital platform economies, which resemble informal economies in many respects. On the other hand, current food markets suffer limitations. Digital platforms can potentially overcome situations in which bulk trade in food markets is dominated by a few dominant traders (oligopsony). Digital platforms could also help to enhance food safety through quality control and tracking consumer feedback and vendor reputation. Taking advantage of the new possibilities of digital platform business models will require governments to update their thinking, however.

A second challenge is that governments and financial institutions need to be prepared to make an initial public investment in digital market development. Our case study suggests that it could be a profitable business to offer a service like Tacaco to a number of markets. This opens the door to a public-private partnership model, which could mobilize entrepreneurs with local knowledge and their own capital. The model will only work at scale, however, when businesses can attend a number of markets held on different days during the week. This would require coordination between various marketplaces. In many cases, private capital may not be enough to enter this business, and startup costs may be too high. Costs need to be managed carefully, as farmers' markets function with small margins. A digital public infrastructure (DPI) would reduce several costs. This would include digital identification of farmers and farms, digital payment systems, among other services. Also, public oversight is needed to ensure that data are managed well, avoiding monopolistic effects. Various stakeholders would need to come together to design a viable model. Such an investment could have substantial benefits, however. Our case study and pilot suggest that investing in a well-designed strategy can achieve the digital long tail effect, and thereby support agrobiodiversity conservation, and use, farm diversification, and healthy diets.

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