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When neglected species gain global interest: Lessons learned from quinoa's boom and bust for teff and minor millet

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ABSTRACT

Until recently, many so-called neglected and underutilized species (NUS) were not present in global markets despite playing a pivotal role in the local livelihoods in their places of origin. Today, some NUS receive substantial global interest and face growing global demands. Sudden increases in consumer demand trigger prices to rise; land-use change at the farm and national levels results in a rapid production increase. This phenomenon is known as "boom" and is usually followed by a "bust", a rapid decrease in prices, and subsequently, production. This review elaborates on the boom-and-bust phases of two NUS: quinoa from the Andes and teff from Ethiopia. We explored the potential upcoming boom of minor millets in India. Our study proposes a generic framework for exploring cross-scale interactions and rethinking sustainability pathways for future NUS booms.

1. Introduction

Over the last decades, dietary analysis in most Western world welcomed the arrival of Neglected and Underutilized Species (NUS) (De Schutter, 2011; Horlings and Marsden, 2011; Li and Siddique, 2018; Magrini *et al.*, 2019). Previously, most NUS were produced and consumed primarily in their places of origin. Nowadays, these crops receive substantial interest (Chelleri et al., 2016; Pallante et al., 2016), especially from health-conscious consumers attracted to their unique nutrient compositions (Li and Siddique, 2018). Due to their increased popularity and swiftly developed innovative marketing, many NUS are now labelled as "superfoods" (Li and Siddique, 2018), further increasing consumer demand and resulting in the rise of prices. Thus, leading to the rapid and significant increase of their production, the so-called "boom" (Hall, 2011).

Crop booms have been well documented; some emblematic examples include palm oil in Indonesia (Gilbert, 2012; Sibhatu, 2019), cacao in West Africa (Clough et al., 2009; Andreotti et al., 2018), coffee in Latin America (Pinilla and Willebald, 2018; Beveridge *et al.*, 2019), and shrimp in South-East Asia (Belton et al., 2017). Booms are generally triggered by rapidly increasing consumer demands from abroad (Hall, 2011), creating market prices rise. Producers thus swiftly change to cultivating the booming crop (Mahanty & Milne, 2016; Ornetsmüller et al., 2018). In the medium- and long-term, the initial benefits of booms tend to negatively affect agroecosystems causing land use to change and affecting local natural resources (McDonell, 2015; Pinilla and Willebald,

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2018). Hence, crop booms are commonly followed by a period of production decline, and finally, by a period of re-growth of crop cultivation. This process is referred to as a boom-and-bust cycle (Clough et al., 2009; McDonell, 2015).

Today, most NUS are actively grown by smallholders in the area where they have been produced for centuries, often in marginal lands, with limited or no external inputs (Altieri *et al.*, 1989; Wezel *et al.*, 2017). The occurrence of crop booms can endanger local food security and farming systems sustainability in these communities when smallholders are encouraged to expand their production rapidly and simplify their farming systems by adapting variety choices and agricultural practices to global standards and requirements of agroindustry (De Schutter, 2011; van Noordwijk et al., 2014; McDonell, 2015). In addition to these acute impacts, other impacts include extensive land conversion, modification of rural landscapes, and changes in farming practices and water management (Chelleri et al., 2016; Minten et al., 2016; van Noordwijk, 2019).

In this paper, we present a literature review of two recent NUS booms: quinoa (*Chenopodium quinoa* Willd.) in the Peruvian and Bolivian Andes and teff (*Eragrostis tef* (Zucc.) Trotter) in Ethiopia. Building on the knowledge from these two cases, we developed a generic framework to explore sustainability transition in NUS boom and bust cycles. We assessed the characteristics of these NUS that led to increased global demands and the resulted boom and bust cycle. In addition, we evaluated the diverse governance instruments that applied to these two cases and their impacts on the cycle. Finally, we considered the upcoming minor millet boom expected to occur in India. Applying our "lessons learned" and framework to minor millets and their upcoming boom can help the actors in the value chain coordinate to learn how sustainable transitions can co-exist in a boom-bust cycle ensuring local benefits and preservation of the social-ecological environment.

2. Literature review

We operated bibliographic searches in Scopus to explore NUS booms. First, we searched for the terms: "quinoa," "teff," "minor millets," "boom," and "neglected and underutilized species." The composite strings we developed yielded zero results for minor millets and boom, teff and boom, neglected and underutilized species, and boom (Fig. 1). We concluded that no papers overlapped with NUS and boom, evidencing a gap in the scientific literature (See Appendix A for a complete overview of the search strings used in Scopus, September 2021).

3. NUS boom and bust cycle

Based on the scientific articles we found, we sketched the boom-and-bust cycle phases which will be key to exploring sustainability transition over past, current, and future NUS boom and busts (Fig. 2). Concerning the complexity and diversity of NUS globally, we developed a boom-and-bust cycle useful to highlight a common ground among the different case studies. Therefore, we identified five cycle phases. In phase 1 or NUS promotion, we pointed to the supply/demand relations and elasticities with a long tradition of economic analysis. Phase 2, or the NUS boom, is a quick phase that involves environmental effects of increased land conversion to agriculture, increasing market production for export, increase in the market and farmgate rates, and an increase in the area harvested. Meanwhile, government programs can try to interact with and influence the above dynamics in multiple ways, through measures that can be top-down or bottom-up. In the third phase, the NUS bust, we described the consequences on food security as well as other concerns about how increased farm income is used and how it leads to changes in local well-being. In this phase, the initial and short-term NUS boom decade in a decreasing interest among stakeholders. Currently, of specific interest is the degree to which growing awareness of local impacts informs and modifies global consumer behavior, sparking response actions that may influence local dynamics and feedbacks in multiple ways. Phase 3 is the longest in terms of time, reducing the benefit obtained by local communities during the boom. As in the case of teff in Ethiopia, phase 3 can be avoided by shifting from the boom phase towards a sustainability transition (Crymes, 2015). In the fourth and fifth phases, new possibilities are developed by and/or for smallholders and local communities that rethink the organization of NUS production, processing, and consumption and re-establish a connection between the different actors. This adds value to NUS local production, commercialization, and place in the global market. In phase 4, we present a common protocol for driving the sustainability transition of the NUS boom and bust following the United Nations' 2030 agenda for

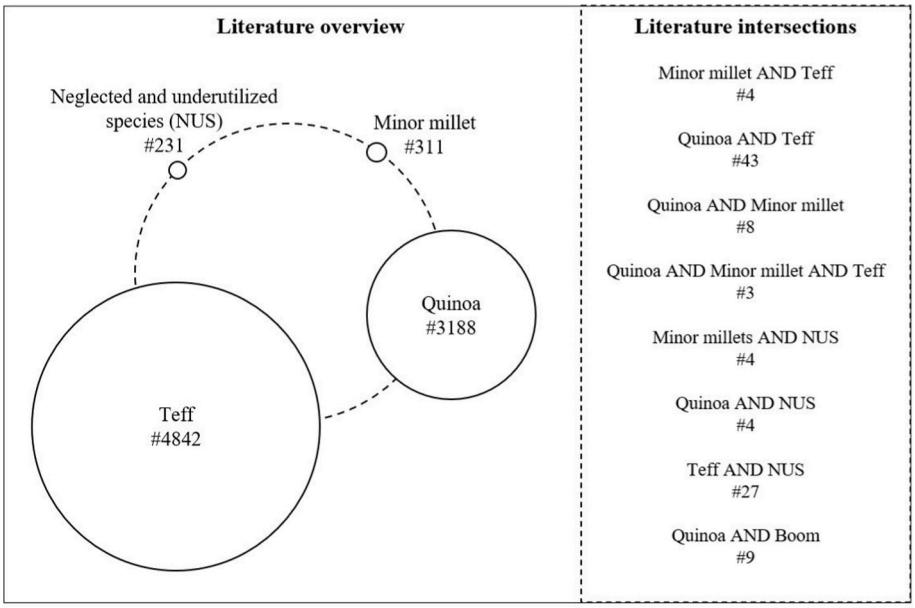

Fig. 1. On the left, proportional diagrams showing the results of the literature search of the four main elements studied: "quinoa", "teff", "minor millet" and "neglected and underutilized species" (NUS). On the right the consequent list of literature intersections including "boom". The intersections that yielded zero are excluded from this figure (Scopus literature search performed in September 2021).

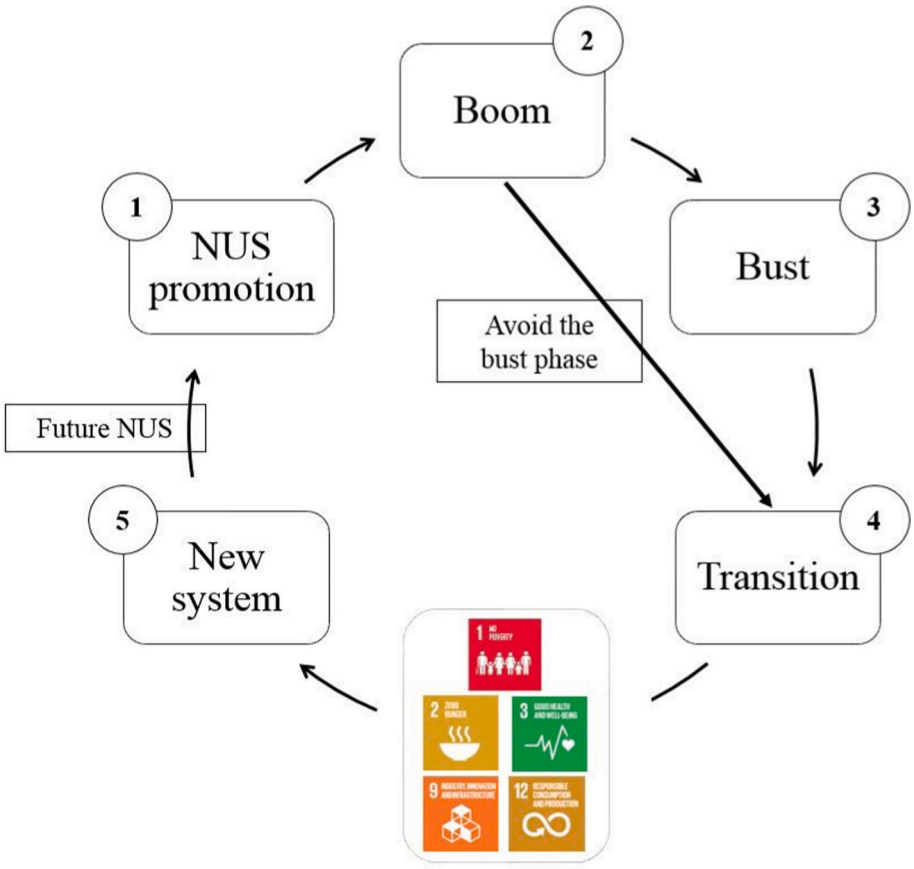

Fig. 2. Phases of the NUS boom and bust cycle. Phase 4 and 5 rely on sustainability transition based on the SDGs presented by the FAO (2018) for developing sustainable food systems, namely: SDGs 1,2,3,9 and 12. These SDGs will be showed in an in depth framework for phases 4 and 5 highlighting a transition path towards sustainability (Fig. 6).

Sustainable Development. In fact, these guidelines not only show the path to inclusive prosperity but also draw a common protocol to follow towards a sustainable future (Veldhuizen et al., 2020). These objectives embrace the principles of sustainability and tackle the root causes of poverty and hunger (Byerlee and Fanzo, 2019; van Dijk et al., 2020). Thanks to this protocol, we aim to present with phase 5 a scheme of recommendations to achieve sustainable NUS production and market. Finally, the cycle presented a continuum process framing possible future NUS boom.

3.1. Phase 1: NUS promotion

3.1.1. Nutrition characteristics of NUS

The first phase of the boom-bust cycle is the promotion of NUS as "superfoods" which attracts new consumers worldwide thanks to the crops' high nutritional values (Padulosi et al., 2013; Zimmerer and Haan, 2017; Pilling et al., 2020). Quinoa, teff, and minor millets have an optimum amount of energy and protein compared to other common cereals (Geervani *et al.*, 1989; Bultosa et al., 2002; Repo-Carrasco et al., 2003; Baye, 2014) (Table 1). The absence of gluten (Hopman et al., 2008; Padulosi et al., 2013) makes these three NUS valuable for preparing dietary products for gluten intolerant people. Furthermore, quinoa, teff, and minor millets possess additional nutritional advantages over many common cereals such as maize, white rice, and wheat. For instance, teff, due to the low glycemic index (74) and high gelatinization temperature (68–80 °C), is a slow-digesting carbohydrate (Wolter et al., 2013; Baye, 2014). Another example shown is that quinoa has the ideal balance of essential amino acids for human diets (Navruz-Varli and Sanlier, 2016).

3.1.2. Phase 1: quinoa

One of the most studied NUS is *Chenopodium quinoa* Willd. (Bazile et al., 2015). Farmers in the Andes in South America took the first steps in domesticating quinoa approximately 7000 years ago (Bazile et al., 2013). Through a multitude of selection procedures, desirable crop traits were selected from different cultures and territories in South America, including parts of Peru, Bolivia, Chile, Argentina, and Ecuador. Traits were selected in relation to the crop's cultivation (Bhargava &

Table 1
Average analysis (g 100 g^{-1} fresh weight) and mineral composition (mg 100 g^{-1} dry weight) of quinoa (Koziol *et al.*, 1992), teff (Geremew *et al.*, 2004), minor millets (Geervani *et al.*, 1989) and other major staples: wheat, maize, and white rice (FAO, 2015).

Crops	Protein	Fat	Ash	Carbohydrate	Crude fiber	Ca	P	Mg	Fe	Zn	K
Quinoa	16,5	6,3	3,8	69	3,8	148,7	383,7	249,6	13,2	4,4	926,7
Teff	11	2,5	2,3	73	3	112,9	429	164	80,8	3,9	615
Minor millet	11,5	3,9	4	63,8	8,6	182	239	109	10,2	2,2	260,5
Wheat	10,6	1,9	1,4	61,6	10,5	108	288	126	4,3	3,5	363
White rice	7,1	0,66	1,3	80	4	28	115	25	3	2	115
Maize	9,8	4,9	1,4	60,9	9	48,3	299	107,9	3	3	324

Srivastava, 2013) and taste preferences (Bazile et al., 2016a).

The last 40 years have seen a great expansion of quinoa production and experimentation globally (Bazile et al., 2013; Katwal and Bazile, 2020). Quinoa was promoted during the International Year of Quinoa in 2013 (IYQ-2013) by the United Nations (UN) (Bazile et al., 2016a). The main purpose of IYQ-2013 was "to focus world attention on the role that quinoa biodiversity plays owing to the nutritional value of quinoa, in providing food security and nutrition" (Bazile et al., 2013; Murphy et al., 2016). The FAO works with national governments to help maintain and protect their quinoa agrobiodiversity, considering seed rules at global and national levels. However, the main decisions for shaping the rules and laws concerning seed and plant genetic resources are developed by national institutions and governments (Bazile et al., 2016b).

Global expansion of quinoa began in the 1950s with increased demand from North America and Europe. Producer countries quickly increased from seven in the Andean region to more than 50 before the IYQ 2013. Today, quinoa is cultivated in more than 123 countries and is present in every climatic zone of the planet (Bazile *et al.*, 2016; Gardner *et al.*, 2019).

For centuries, Andean quinoa products were denigrated and destined only for household consumption (Bazile et al., 2013). Today, quinoa has made its way into the diets of urban populations not only in Andean countries but also in the United States, Europe, and Asia (Bellemare et al., 2018), where a wide range of quinoa products are now available in shops from ready-to-eat meals or breakfast cereals to healthy snacks, noodles, beverages, and beers. This, in part, is due to international recognition following the IYQ-2013. These products are well positioned in several niche markets such as the nutraceutical, organic, and fair-trade markets (Carimentrand et al., 2015). These last 50 years of quinoa expansion at a global level offer lessons for understanding what is now happening for other NUS.

3.1.3. Phase 1: teff

Teff (*Eragrostis tef* (Zucc.) Trotter) is a fine grain cereal belonging to the Poaceae family, believed to have been first domesticated in Ethiopia approximately 3000 years ago (Vavilov, 1951; Ketema, 1997). So far, up to 4000 varieties of teff have been identified in Ethiopia, yet, locally, they are all classified into three major classes: white, red, and mixed (brown and white) (Ketema, 1997; Gizaw et al., 2018).

While quinoa became one of the main cultivated crops in the Andes at the regional level after their international boom, teff was already a major economic staple food grain in Ethiopia before the boom. Teff supports more than 60–75% of Ethiopia's population as a staple food (Crymes, 2015; Gizaw et al., 2018). It takes the largest share of all staple grains, 28.5% of the total cereal cultivation area and about a quarter of the total cereal production (Crymes, 2015; FAO, 2015). Besides its nutritional value, teff is a key cash crop, as 36% of the total national production is commercialized for local and global markets, with 34% higher value than coffee (Worku *et al.*, 2014, Minten et al. (2012).

In Ethiopia, teff is traditionally used to prepare *injera*, a thin, sour, pancake-like food, which accompanies the majority of the daily meals (Bultosa et al., 2002; Baye, 2014). Teff is also used to prepare other foods, like porridge, unleavened bread, and soup (Bultosa et al., 2002). Teff holds a crucial role in the country's social, economic, cultural, and political functioning and well-being (Wolter et al., 2013).

3.2. Phase 2 and 3: NUS boom and bust

3.2.1. Quinoa boom and bust

After the International Year of Quinoa (2013–2015), 26 countries, the majority in Africa, received the FAO's technical assistance to strengthen food security by promoting quinoa cultivation (Bazile et al., 2016b). The markets for Andean exports also changed. The USA became a more important importer, concentrating 56% of the shipping from Bolivia, Ecuador, and Peru (Alandia et al., 2020). Germany, France, the Netherlands, and Japan lost relative weight as buyers, but their imports continued to increase. This occurred in the context of increased traded volumes in the global market. In fact, traditional international consumers and importers from outside the Andes now produce quinoa in their own countries (Bazile et al., 2016a).

One impact of the growing global interest in quinoa associated with IYQ was a rapid increase in international prices during a short period, with a peak in 2014 (Fig. 3 and Fig. 4) (IICA, 2015). The farmers benefitted from the price rise thanks to fair trade circuits. At the same time, many rural landowners who migrated to the cities years ago came back to their communities to grow quinoa (Risi et al., 2015; Tschopp et al., 2018, 2019). Andean countries had to rethink and update their public policies, prioritizing the sustainability of the crop and re-evaluating quinoa as a grain of global importance (Murphy et al., 2016). However, Andean countries showed an increase in per capita consumption due in part to the fact that quinoa being internationally recognized changed its status at the national level and was now commercially more available for Andean local consumers in various novel consumer forms. In addition, government plans were implemented in Peru and Bolivia to favor quinoa consumption (Risi et al., 2015; Bellemare et al., 2018), resulting in the doubling of national quinoa consumption rates in Peru as well as exported volumes yearly (Bazile, 2015).

Peru and Bolivia remain the two main producers of quinoa (Carimentrand et al., 2015). Recently, many countries (>117) in North America, Europe, Asia, and Africa have also expanded their quinoa production (Bazile et al., 2016b; Choukr-Allah et al., 2016; Gardner *et al.*, 2019) while continuing to import the majority of their national quinoa consumption (Murphy et al., 2016; Bazile et al., 2021).

3.2.2. Teff boom-and-bust control

Several studies have identified the major drivers for the price escalation of teff in Ethiopia as both internal and external factors (Crymes, 2015; FAO, 2015; Gizaw et al., 2018; Minten et al., 2012) (Fig. 5). Internally, the rapidly growing non-farming population coupled with slowly improving productivity of the farming system continually widened the demand-supply gap of teff (Gizaw et al., 2018). Externally, growing foreign demand, mainly from the African diaspora, caused the export of teff to rise significantly, which negatively affected local markets (Chen *et al.*, 2015; Minten et al., 2016).

To stabilize markets, the government banned the export of teff grain and flour in 2006. However, the measure was inefficient, as the export of processed products like *injera* expanded, keeping teff rates high and increasing (Crymes, 2015; Minten et al., 2012). On the other hand, the recent global recognition and promotion of teff as a gluten-free grain and as one of the superfoods of the 21st century has caused the existing pressure of foreign demand on the local price of teff to be even stronger (Crymes, 2015; Gizaw et al., 2018; Minten et al., 2012). Consequently, the current teff prices have already become unaffordable for most Ethiopians (Crymes, 2015), and the food and nutrition security of the whole nation is now under threat (Gizaw et al., 2018).

Ethiopia, the world's biggest producer of teff, currently does not benefit from this international trade opportunity because of the export ban (Crymes, 2015; FAO, 2015). Furthermore, the country is missing other options to solve its crucial problems of the teff sector, such as low productivity and lack of value-adding processing facilities, which could be cost-effective and faster if the involvement of international players were allowed (Di Marcantonio and Demeke, 2013). Given the rapid economic progress and urbanization witnessed in previous years, as well as increased export demand, the importance of teff in food systems in Ethiopia is anticipated to increase in the coming years. Subsequently, guaranteeing reasonable efforts to meet the growing demand of teff has become a priority for agricultural and food policy in Ethiopia.

3.3. Phase 4 and 5: NUS sustainability transition to a new system

We highlighted the importance of consumer social responsibility that

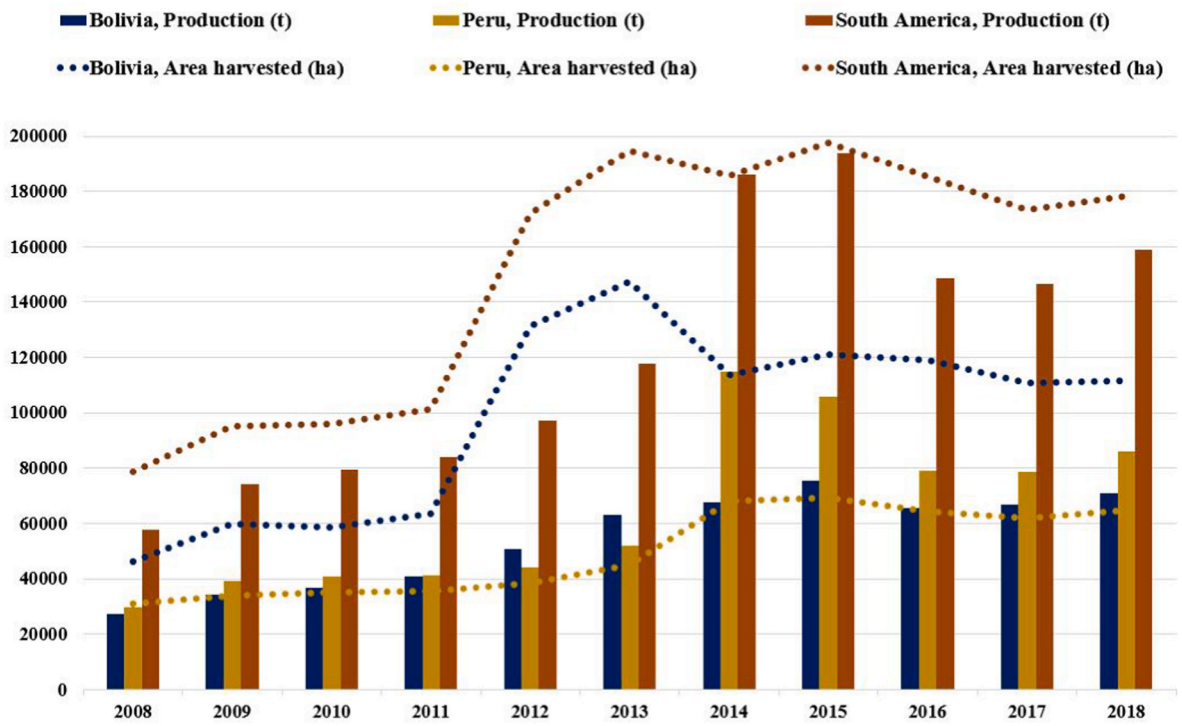

Fig. 3. Harvested area (ha) and production (t) of quinoa in the Andes (Data source: FAO STAT 2018).

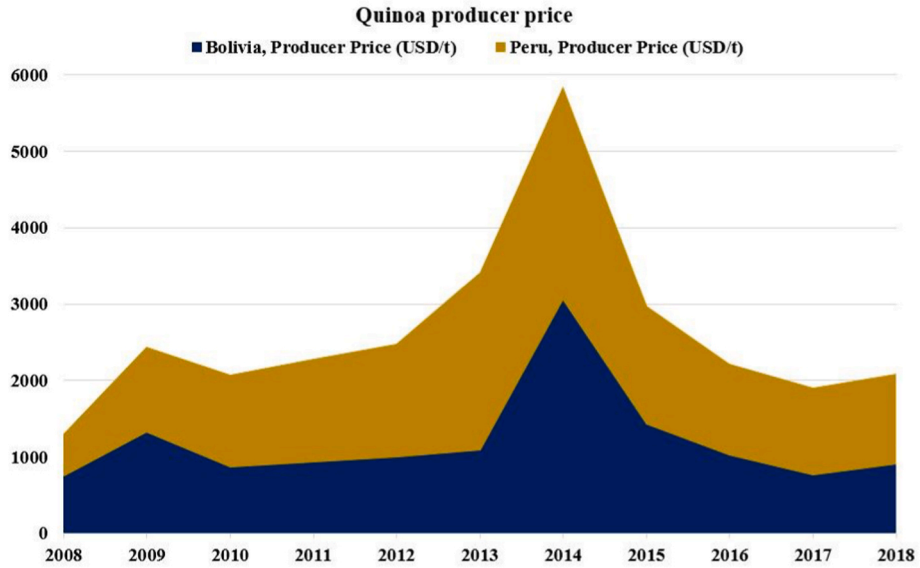

Fig. 4. Producer price (USD/t)) of quinoa in Peru and Bolivia (Data source: FAO STAT 2018).

may be needed to make NUS boom-bust cycles more manageable and supportive of food security and sustainable production practices. We showed new possibilities developed by and for smallholders and local communities that rethink the organizations of production, processing, and consumption of NUS and re-establish a connection between different actors, adding value to NUS local production and commercialization and acting in the global market.

3.3.1. *Quinoa system transition*

In conjunction with the IYQ 2013 (Bazile et al., 2013), the Peruvian and Bolivian governments promoted the creation of the International Quinoa Center in 2013. The center's leverage power is yet unknown as the center only developed its strategy in 2017; however, its objectives include working towards more sustainable and transparent quinoa production and sale and promoting research and stakeholder collaboration. In 2014, Andean quinoa entered international markets, Bolivia was surpassed by Peru as the world's most important quinoa producer, and newly certified protected varieties were registered in the *International Union for the Protection of New Varieties* (UPOV). Small producer markets emerging across Europe and North America were all warning signs that Bolivia might lose its exclusivity on international markets (Carimentrand et al., 2015). Bolivia responded to this threat by increasing its production of highly valued varieties, like the quinoa *real* and by using denomination of origin as a branding and marketing strategy (Laguna, 2003; Risi et al., 2015).

In the case of quinoa, the current understanding of the agricultural

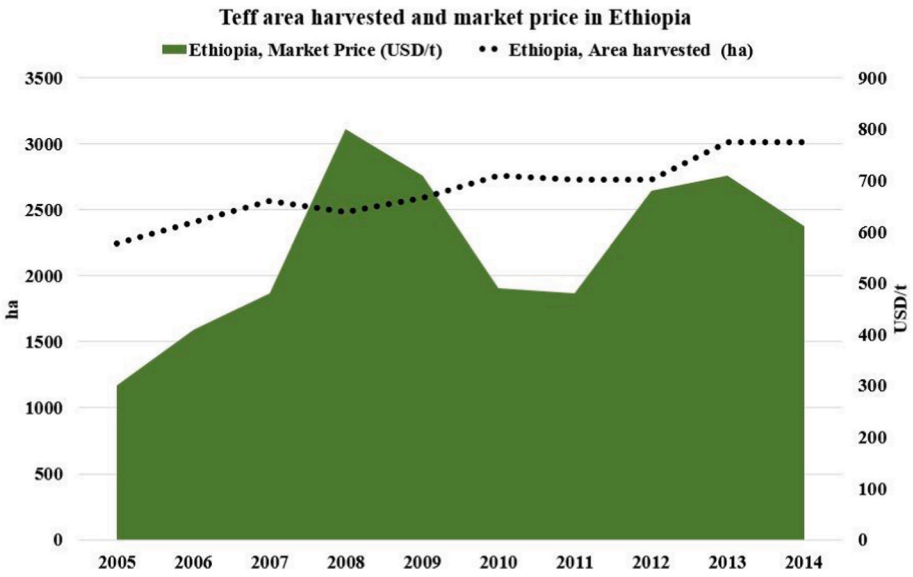

Fig. 5. Harvested area and market price of teff in Ethiopia (Data source: FAO STAT 2018).

boom lacks a collective plan to ensure local benefits from the whole value chain (Tschopp et al., 2018). In fact, several different dynamics occur within different groups of farmers and NGOs. On the one hand, these have the common objective of adding value to Andean quinoa through various niche export markets and staple food of their diet. On the other hand, there is a lack of coordination between these initiatives (Angeli et al., 2020). The lack of stakeholders' communication and organization and transformation plants, Peruvian quinoa, unlike Bolivian quinoa, does not have the necessary qualities to become a niche-market product. While, due to the lack of understanding and action on behalf of consumers, the SDGs highlighted by the FAO (FAO, 2018) are poorly implicated in the chain exposing the Peruvian quinoa production system as an unsustainable food system whose market is not able to sustain its context.

3.3.2. *Teff system transition*

In Ethiopia, the teff boom was quickly controlled by the national government. The Ministry of Agriculture and Natural Resources and its respective offices at the lowest administrative level, *kebele*, are Ethiopia's main and first responsible governmental structure for improving the shortcomings of teff value chains. The ministry is responsible for the promotion of improved agricultural technologies for farmers. It also facilitates and ensures the accessibility of fertilizer and improved seeds to local farmers at a fair price. As the ministry structure stretches from national to village level, it currently serves as an effective extension channel through which farmers are informed of new local technologies developed by the National Agricultural Research System of Ethiopia (FAO, 2015).

In an attempt to safeguard national food security and maintain the existing role of teff as a key food and cash crop, the government of Ethiopia banned the export of teff grain and flowers. As a result of this export ban, teff exports came to a complete stop. However, the ban could not stop or reverse the vastly rising local prices (Hauenstein, 2015). There are currently two main conflicting opinions about the ban's impact (Lee, 2018). The first view argues that the policy has already failed and even holds farmers back from benefitting from a new international niche market. According to this view, lifting the export ban could increase farmer income from teff, thereby their access to food available on the market. In addition, it would promote the national currency reserves and enhance the state's capacity to invest in modern agricultural inputs and technologies for producing food crops. The counter-opinion sees the export ban as a way to protect local farmers from price volatility and the potential monopoly of multinational companies (Hauenstein, 2015). Lifting the ban would reduce the availability and the affordability of teff in Ethiopia, subjecting most Ethiopians to cheaper and less nutritious substitutes. It will also expose Ethiopians to a growing risk of substandard teff products, ultimately harming consumers' health and nutritional status (Crymes, 2015; FAO, 2015; Hauenstein, 2015).

The current understanding of the teff boom in Ethiopia and the societal willingness to act is more in line with effective top-down coordination guided by the government. Imposing a ban on teff regulated the market positioning of teff and *injera* as unique products, which appeal to local and global markets. On the other hand, decoupling monetary value with social and cultural value transform the purpose of teff cultivation from staple food to a cash-generating crop. The main cause for such change is largely related to the rapid rise of teff's domestic market price, which left a huge number of growers with no better option but to use their teff as a cash crop and use the cash to buy cheaper cereals like maize (Jemal et al., 2018). Furthermore, the teff consumption pattern of non-farming rural and poor urban consumers changed as they could not afford teff due to the high prices. Consequently, they either blend or totally replace teff flour with cheaper flours such as sorghum and maize during *injera* making. Due to this change of diet, people with nutrition deficiencies are increasing in rural areas around the city of Addis Ababa (Lee, 2018). In this area, there has been a recent increase in health problems related to iron deficiency (Central Statistical Agency Ethiopia, 2016). Replacing teff with less nutritional crops such as maize or sorghum and with less iron goes against the survival of farmers and the preservation of their socio-ecological environment (Minten et al., 2016).

3.4. *Upcoming NUS boom and bust: the case of minor millets in India*

In India, another traditional grain and food has been labelled as an NUS and is currently drawing the attention of political leaders, researchers, environmental activists, and urban middle-class consumers. These grains are known as millets. Millets are a family of grass-like grains commonly separated into two categories: those with husks called minor millets and those without husks called major millets.

3.4.1. *The evolution of minor millet production and consumption*

Both major and minor millets have been eaten in India for centuries and are part of folklore and culinary traditions in many regions of the country (Chera, 2017; Bath *et al.*, 2018; Li and Siddique, 2018).

Throughout the latter half of the twentieth century, the production and consumption of millets, particularly minor millets, declined across India (Bhalla and Singh, 2009; Shah, 2021). Several reasons explain why minor millets were negatively impacted by the changes during the Green Revolution. Many authors suggest this is due to the policies of the Green Revolution, which favored rice and wheat production (Shah, 2021), in addition to the drudgery involved in the processing of minor millets in order to remove their complex heterogeneous husks (Hazareesingh, 2020).

Following the Green Revolution, India achieved self-sufficiency in food like never before (Shah, 2021). However, today, India faces a triple burden of malnutrition (Gomez et al., 2013). This means there is the simultaneous presence of hunger, malnutrition, and over-nutrition. Hunger is still present but overall on the decline in India, but there is a lack of adequate micro-nutrient intake, particularly in rural areas; malnourishment affects as many as 189 million people in India, which is 25% of the global malnutrition rate (FAO et al., 2020). This can lead to stunting and many life-long health risks for children and mothers. Meanwhile, mainly in urban areas, residents experience a surplus of caloric and macro-nutrition, resulting in a significant increase in cardiovascular diseases and diabetes in the country (Shah, 2019). In this context, the Indian staples, rice and wheat, the keystone crops of the Green Revolution, have been examined critically. The low micro-nutrient qualities, low fiber, and high sugar content of rice and wheat have been highlighted (Chera, 2017).

In addition to this health and food insecurity, India is also facing an unprecedented rural and agricultural crisis which have been documented by both the press and academia (Vasavi, 2009, 2012; Nagaraj et al., 2013; Shah, 2021). In the past thirty years, more than three hundred thousand farmers have committed suicide (Shah, 2021).

One aspect of this crisis is the depletion and pollution of the country's water resources affecting at least 60% of India's districts (Vijayshankar et al., 2011). Farmers and their families are thus vulnerable to health hazards due to numerous pollutants found in groundwater, such as fluoride, arsenic, and mercury. Farmers are also struggling to obtain access to irrigation as drought frequency and severity increase. In addition, yield response to the application of increasingly more expensive chemical inputs is failing (Indoria, 2018). This means higher costs of cultivation without a corresponding rise in output. As this intensified, it compelled farmers to draw increasing amounts of water from the ground (Shah, 2021). The Indian Council for Research on International Economic Relations (ICRIER) estimates that about 78% of India's water is consumed for agriculture and that rice, wheat, and sugarcane consume more than 80% of irrigation water (Sharma *et al.*, 2018). The main reason farmers grow such crops, even in areas of water shortage, is the incentives that exist for them, including steady markets (Shah, 2021).

India's health and food security have changed since the onset of the Green Revolution. The intensive and resource-demanding agricultural practices behind rice and wheat production are slowly being questioned as India faces complex agricultural, environmental, and nutritional crises. The situation described above has generated concern among several actors, some of whom see millets, the traditional and forgotten crop, as a possible solution to these complex situations.

3.4.2. *The boom and the potential bust of minor millets in India*

Millets have been the object of multipronged institutional campaigns aiming to increase urban demand as well as rural production in multiple states of India like Odisha and Karnataka. The state governments promote millets as "*Good for you, good for the farmer, and good for the Earth*" (Government of Karnataka, 2018). In contrast to rice and wheat, millets present nutritional characteristics which could help buffer both the lack of micro-nutrition and the presence of lifestyle diseases like diabetes. Millets have always been dryland crops; they grow well without irrigation and are drought-resistant (NAAS, 2013). Their official national nomenclature was even modified in 2018, from coarse cereals to nutri-cereals, to help forget the implicit inferior status they once had (Financial Express, 2018).

Indian urban demand for minor millets has increased, especially among the upper-middle class of South Indian cities like Bengaluru, Mysuru, and Chennai (Krishna et al., 2013). Trendy restaurants and shops are increasingly including millets on their menus and shelves and promoting them as smart foods, nutraceuticals, or the food of the future gifted to us by our ancestors. Traditional recipes are being modified, and new ones are created to make millets appealing to young urban consumers (Chera, 2017).

Various national agricultural research institutions are seeking to develop high-yielding and hybrid varieties as well as the appropriate machinery for hulling, grading, and processing of millets into high-value products adapted to new urban consumption patterns and possibly for export markets (Padulosi et al., 2015).

A national year of millets was declared in 2016, and India was part of the committee to submit the proposal to the FAO for an International Year of Millets which took place in 2018. The proposal was successfully resubmitted for the year 2023 (Li and Siddique, 2018). There are multiple attempts to create an international export market for millets, which in the meantime does not exist.

As detailed above, many actors with different backgrounds, intentions, and values, have jumped onto the millet bandwagon. From these observations, it is possible to confirm that minor millets have been and continue to be in a promotion phase, or Phase 1 of the boom-and-bust cycle, since the mid-2000s. Minor millets are perhaps currently in Phase 2 (boom) of the boom-and-bust cycle.

The patterned trajectories of miracle development crops and NUS are well known (McDonell, 2020). If minor millets are currently experiencing a boom, the question is whether a bust is unavoidable? Could certain policies, a sustained consumer demand, or NGO involvement perhaps diminish the possibilities of a bust? How could the potentially beneficial effects of millet production be measured, broadened, and maintained over time? What lessons can be learned from other NUS bust experiences?

In addition, if minor millets are to experience a boom-and-bust cycle, their promise of resolving complex climatic and health issues is compromised. The value of minor millets is not only connected with their economic value but also their ecological value, which needs to be ensured and maintained over a potential boom-and-bust. Policies can be used to protect local varieties and specific modes of production, which could protect millets from losing their ecological edge developed over the years by local farmers and organizations (Nagarajan et al., 2009; Padulosi et al., 2015). Also, the absence of appropriate political and economic protection could lead to large-scale and intensive production destined for markets outside the rural areas and prevent local consumption, thus part of the millets potential. Long-term partnerships between governments agencies, local organizations, and farmers seem necessary to avoid the instability inherent in NUS booms.

Millets are being promoted in India because they are viewed as an alternative, even as a solution, to specific health and environmental challenges in contemporary India. However, an increase in production and consumption of minor millets is not sufficient to resolve these complex crises the country is experiencing. Millets could be one element of an ensemble of alternatives, perhaps even a paradigm shift (Shah, 2021).

3.5. *Inclusive action decision towards sustainable NUS production and consumption*

Our analysis based on our NUS study cases shows the poor connection between producers and consumers. The gap in scientific research also shows a lack of understanding about consumers' role in the NUS boom and bust cycle (Fig. 6). More research seems needed to study the ethical issues of far-away health-focused and conscious consumers. In fact, as we described, the NUS boom and bust may lead to unknown consequences for the consumers, such as food insecurity in the place of

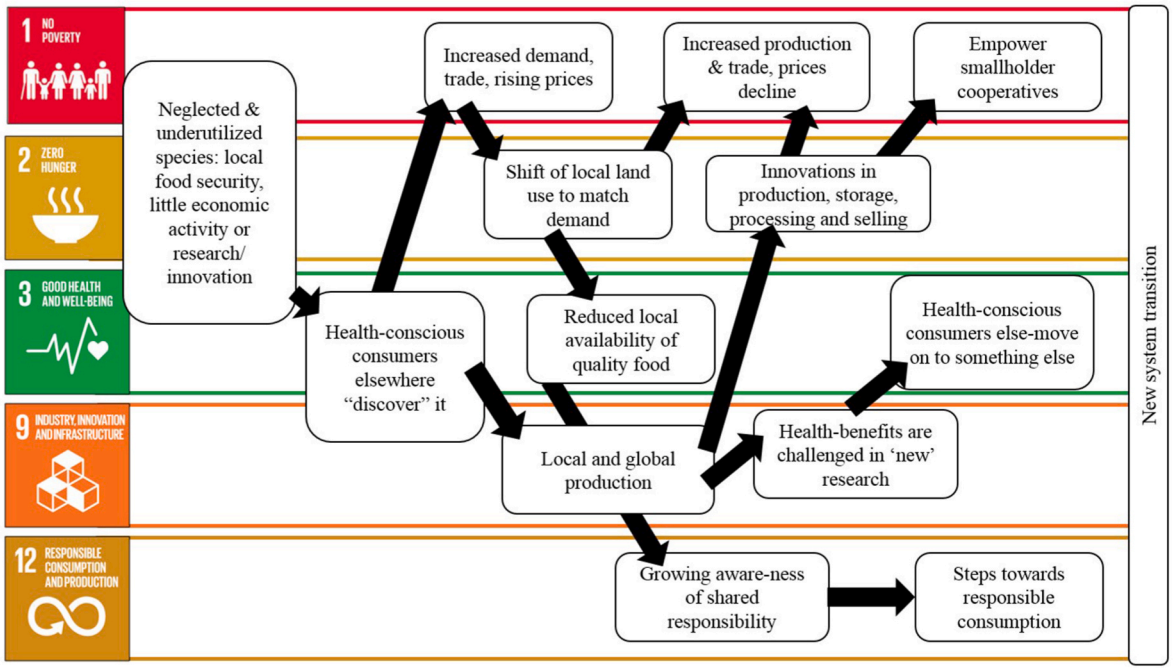

Fig. 6. Sustainability transition framework highlighting processes for a new system transition (Phases 4 and 5 of Fig. 2). The five SDGs presented, namely 1,2,3,9 and 12, are the grid of the processes to analyse the transformation over time.

production and origin, simplified local food systems, and indirectly reducing the genetic diversity maintained for centuries. This challenge needs a more inclusive approach to promote an active decision-making process and future scenario evaluation.

Inclusive active decision-making and initiative promoted by local and international institutions may drive a more sustainable NUS supply chain (Speelman et al., 2014, 2019; Andreotti et al., 2020; van Noordwijk et al., 2020). For instance, in Chile, a prospective scenario for the future of quinoa was explored with farmer organizations from three different regions, cultures, and practices, using a role-playing game for discussing how to enhance coordination among them and for connecting their organization to extension services and national programs (Bazile et al., 2012a, 2012b). The main result was the creation of round-table discussions, the so-called "*Mesa nacional de la quinoa*" by the Chilean Ministry of Agriculture for debating with all actors involved in quinoa development about options for better use of public funds with local communities. A similar strategy has also been adopted by the Peruvian Ministry of Agriculture with the so-called *"Mesa de la quinoa"* fostering new opportunities and cooperation between the main quinoa producers in the Andes (Mercado and Ubillus, 2017). Following up the experience of the "*Mesa nacional de la quinoa*" in Chile, a more recent and ongoing PhD project presented during the *Forum Origin, Diversity and Territories* aims to directly involve Andean quinoa producers – from multiple Andean countries - for developing a collective trademark for Andean quinoa (Andreotti et al., 2020). Coordinating collective action by connecting local actors with consumers can facilitate a better understanding of the NUS boom and bust cycle and open the discussion for co-designing sustainable future food systems. To achieve this, an inclusive, participatory approach at the transnational value chain level is needed.

4. Conclusions

Research shows that crop booms of neglected and underutilized species (NUS) have often resulted in negative impacts in the medium and long-term for farmers, their livelihoods, and the landscapes they live in. In this paper, we reviewed the recent agricultural booms of quinoa and teff as a result of increased demand from health-conscious consumers in the Western world. We reflected on two distinct approaches used to manage these two booms, namely a bottom-up approach in the case of quinoa initiated by Andean farmers' organizations and a top-down approach in the case of teff supported by the national government. In the case of quinoa, a grassroots approach was used by local stakeholders to achieve positive outcomes for local landscapes and the livelihoods of quinoa farmers. In the case of the teff boom in Ethiopia, a top-down approach was used to secure national food security for the country's staple food and prevent bio-piracy of their endemic genetic resources. While in Peru and Bolivia, farmer organizations unified their efforts to launch a more sustainable export approach. In Ethiopia, the national government imposed a temporary ban on teff exports to mitigate the boom-bust effect. Drawing from the lessons learned from these two booms, we reflected upon the nascent minor millets NUS boom in India and how millets could be integrated into agricultural production and consumption in a long-term and sustainable fashion. We question if the boom-and-bust cycle is inevitable and if strong partnerships between government, researchers, local organizations, and farmer groups are not the best way to ensure that the millet potential delivers not only for urban consumers but also for rural farmers and farmer families.

Declaration of competing interest

The authors declare that they have no known competing financial interest or any other conflicts of interest.

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Appendix A

Overview of the search strings, including articles' title, abstract, and keywords carried out in Scopus in September 2021.

- "Neglected and underutilized species" OR "NUS": 231 hits
- "Teff": 4842 hits

- "Quinoa": 3188 hits
- "Minor millet*": 311 hits
- "Minor millet*" AND "Teff": 4 hits
- "Quinoa" AND "Teff": 43 hits
- "Quinoa" AND "Minor millet*": 8 hits
- "Quinoa" AND "Minor millet*" AND "Teff": 3 hits
- "Minor millet*" AND ("Neglected and underutilized species" OR "NUS"): 4 hits
- "Quinoa" AND ("Neglected and underutilized species" OR "NUS"): 4 hits
- "Teff" AND ("Neglected and underutilized species" OR "NUS"): 27 hits
- "Quinoa" AND "Boom": 9 hits
- "Minor millet*" AND "Boom": zero hits
- "Teff" AND "Boom": zero hits
- "Neglected and underutilized species" AND "Boom": zero hits

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