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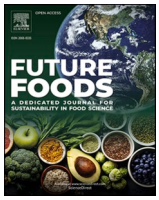

The role of neglected and underutilized species (NUS) in sustainable development goals (SDGs): The case of sea buckthorn value chain in rural China

Haoxu Zhang [a,*], Elena Millan [a], Kevin Money [b], Pei Guo [c]

[a] Department of Agri-Food Economics and Marketing, University of Reading, Reading, UK
[b] The John Madejski Centre for Reputation, Henley Business School, University of Reading, Reading, UK
[c] College of Economics and Management, China Agricultural University, Beijing, China

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ABSTRACT

Neglected and underutilized species (NUS) can play a crucial role in food and nutrition security, agricultural diversity and resilience, poverty reduction, and income generation. Given the importance of NUS in achieving sustainable development goals (SDGs) without notable trade-offs, this study conducts in-depth interviews with sea buckthorn value chain stakeholders in three counties in Gansu Province, China, to understand key drivers for creating new NUS value chains, the strengths, weaknesses, opportunities, and threats (SWOT) of each type of value chain stakeholders, and the role of NUS for sustainable development. The findings show that four drivers, namely infrastructure (e.g., rural roads for logistics, information and communication technology facilities for e-commerce), investment (e.g., agricultural loans/subsidies), scientific and technological (e.g., advanced processing equipment, research on breeding and strategic plantation), and market drivers (e.g., offline and online e-commerce platforms) have better integrated internal natural and human capital and external financial, physical, and social capital into NUS value chains. The study proposes a novel conceptual framework for the adoption of the NUS value chain, highlighting the significant potential of NUS in achieving a balance between the economic, social, and ecological objectives of the SDGs at a regional level through responsible and strategic plantation, production, processing, marketing, and consumption of NUS.

Industrial relevance

First, this study proposes a holistic conceptual framework that enables practitioners to systematically consider five forms of capital—natural, human, physical, financial, and social — alongside four key drivers: infrastructure, investment, scientific and technological, and market forces, before adopting new NUS value chains. Second, the findings can inspire the food industry to integrate more plant-based NUS with strong sustainability appeal into their product offerings aligned to evolving consumer needs.

1. Introduction

The United Nations 17 Sustainable Development Goals (SDGs) provide an integrated framework calling for collective action and global partnership to achieve sustainable development by 2030. At the core of sustainability lies the concept of inclusive development (Gupta and Vegelin, 2016; Arts, 2017), which encompasses three critical dimensions (1) social inclusiveness (i.e., reducing poverty (Collier, 2008)), (2) ecological inclusiveness (i.e., protecting local ecosystems ensuring ecosystem services (Steffen et al., 2007)), and (3) relational inclusiveness (i.e., mitigating social inequality (Stiglitz, 2015) and encouraging participatory governance (Lawson, 2010)).

Yet current initiatives predominantly emphasize economic growth and social inclusiveness, often at the expense of ecological and relational inclusiveness (Gupta and Vegelin, 2016; Meybeck et al., 2024). Among

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* Corresponding author at: School of Agriculture, Policy and Development, Earley, Reading, RG6 6BZ, United Kingdom
E-mail address: haoxu.zhang@pgr.reading.ac.uk (H. Zhang).

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the 17 SDGs, 13 focus on social inclusiveness, 7 target ecological inclusiveness, and only 3 explicitly address relational inclusiveness (Gupta and Vegelin, 2016). Similarly, the Resilient and Inclusive Transformation Impact Initiative (RITII) initiated by the Food and Agriculture Organization (FAO) prioritizes social inclusiveness by championing the principle of "leave no one behind" to enhance resilience of livelihoods and agri-food systems (Meybeck et al., 2024), while ecological/relational inclusiveness receive comparatively less attention. Achieving strong sustainability necessitates a balanced approach that integrates social, ecological, and relational inclusiveness within the framework of inclusive green growth (Fay, 2012). Therefore, ensuring equal emphasis on all three dimensions is essential for the successful implementation of the SDGs and initiatives such as the RITII (Gupta and Vegelin, 2016).

While trade-offs among different SDGs are often observed at the macro level, the adoption of neglected and underutilized species (NUS) presents a viable micro-level solution that can simultaneously promote income growth for marginalised farmers and biodiversity conservation (Will, 2008; Bjarklev et al., 2019), as most documented NUS are wild or domesticated by traditional smallholder farmers in developing countries (Schmidt et al., 2008). NUS adoption embodies the principles of inclusive green growth without notable sacrifices among competing goals.

The increasing academic focus on NUS underscores their potential to contribute significantly to achieving SDG 2 (Zero Hunger), particularly in developing and low-income countries. Between 2019 and 2022, academic attention to NUS has doubled, highlighting their role in enhancing nutrition and food security (Talucder et al., 2024). Specifically, NUS have been shown to support food security and nutrition (Padulosi et al., 2013; Hunter et al., 2019; Pieterse et al., 2023), promote genetic diversity and sustainable production (Dansi et al., 2012; Pieterse et al., 2023), generate income for smallholder farmers, and contribute to poverty reduction (Magbagbeola et al., 2010; Padulosi et al., 2013).

A global slow food (SF) grassroots movement has also attracted public attention, advocating for a holistic approach to gastronomy that links food to people, cultures, ecosystems, and well-being while safeguarding neglected and endangered foods within their sociocultural and ecological contexts (Barstow et al., 2021).

The use of NUS offers a promising pathway for the implementation of the SDGs, prompting several critical research questions: (1) How can NUS value chains be established and industries developed to generate income for local communities? (2) How can marginalised populations be integrated into NUS industries to create inclusive value chains that sustainably benefit all stakeholders in the value chain? (3) How can the utilization of NUS and the collaboration among stakeholders promote sustainable development? Addressing these questions underscores the need for further empirical investigations to provide deeper insights into the role of NUS in sustainable development.

This study focuses on a typical NUS, sea buckthorn, as our research subject, conducting face-to-face semi-structured interviews with various stakeholders along the sea buckthorn value chain in three formerly national-level poverty-stricken (NP) counties[1] in Gansu Province, China. Sea buckthorn was long regarded as a NUS growing wild under natural conditions in arid, sparse vegetated mountainous regions of Northern China; however, the adoption of sea buckthorn value chains, together with increased market visibility through e-commerce has enabled its successful commercialisation. Beyond its role as nutritious and healthy foods, sea buckthorn creates social and environmental benefits, including poverty alleviation and desertification control. These characteristics make it a valuable case for exploring the research questions outlined above.

[1] China published a list of national-level poverty-stricken counties in 2012 at the stage of targeted poverty alleviation, and by the end of 2020 all the counties were moved out of the list as extreme poverty was eliminated (The State Council Information Office of the People's Republic of China, 2021).

This case study provides novel insights into the significant role of NUS, particularly sea buckthorn, in balancing the economic, social, and ecological dimensions of the SDGs. The contributions of this study are threefold. First of all, the study, for the first time, identifies four key drivers, which are infrastructure improvements, investment boost, scientific and technological advancements, and market forces, along with push-pull strategies that facilitate the adoption of NUS value chains. It also shows that the interaction of these drivers can have synergic benefits, integrating natural, human, financial, physical, and social capital into the value chain. Furthermore, by analysing strengths, weaknesses, opportunities and threats (SWOT) of value chain stakeholders, this research highlights the importance of responsible and strategic NUS plantation, production, processing, marketing, and consumption to overcome challenges for the sustainable development of local NUS industries. This research offers the first documented case study that successfully commoditizes NUS in remote rural areas. More importantly, this research contributes to the broader discourse on sustainability of food systems by proposing a holistic conceptual framework for utilizing NUS to achieve inclusive green growth and nurture resilience in food systems and rural communities. This framework enables practitioners to systematically consider five forms of capital alongside four key drivers when making decisions about adopting new NUS value chains. This study also calls for action to integrate more plant-based NUS into the food industry.

2. Literature review

2.1. The role of NUS in sustainable development

The SDGs project a future of inclusive green growth (Fay, 2012), and sustainability is built on optimizing economic, social and ecological dimensions (Gupta and Vegelin, 2016). However, recent literature has shown that even achieving two of the three aspects is difficult due to notable trade-offs (Bowen et al., 2017; Barbier and Burgess, 2019; Kroll et al., 2019).

Inclusive growth is a combination of economic growth and inclusive society, which emphasizes improved productivity and newly created employment opportunities to reduce poverty and inequality (Aslam et al., 2020). However, efforts towards inclusive growth are far from enough, let alone improving environment quality alongside inclusive growth.

Amid accelerating climate change and ecological breakdown, green growth that aims to decouple GDP growth from resource use and carbon emissions has also become a key topic of discussion (Hallegatte et al., 2012; D'Alessandro et al., 2020; Hickel and Kallis, 2020), but most studies indicate that it is challenging to achieve green growth. Even putting economic growth aside, building a green society that supports poor and marginalized populations is not an easy goal (Haase et al., 2017; Chancel, 2022; Ogunbode et al., 2024)

Table 1 presents main arguments from previous studies about the trade-offs among economic, social and ecological goals of the SDGs. Therefore, the solutions balancing these three dimensions should be given significant importance and prioritized during the implementation process.

NUS are plant varieties or species that have been traditionally cultivated or consumed in specific, often localized, environments but have received little attention in modern agricultural systems by researchers, plant breeders, policymakers, and other stakeholders (Will, 2008; Padulosi et al., 2013). These species are wild or semi-domesticated, adapted to harsh and marginal environments, embedded in the cultural traditions of local communities, and typically not commercialized as commodities, despite their multifaceted benefits (Talucder et al., 2024).

The contribution of NUS to social inclusiveness has been commonly recognized in developing countries. Different from major cash crops, NUS, the so called 'minor species', are often tolerant to abiotic stress

Table 1
Main arguments about trade-offs among SDGs across regions.

Region	Main arguments	Source
Global	Income inequality within developed and developing countries has been growing over decades, undermining inclusive growth (SDG 8) and the effectiveness of poverty reduction strategies (SDG 1).	(Ravallion, 2014; Hoffmann et al., 2020)
Global	Between 2000 and 2015, the world might have made more progress toward goals of no poverty, clean water and sanitation but possibly at the expense of other environmental goals.	(Barbier and Burgess, 2017)
Global	Green growth faces synergies and trade-offs.	(Hallegatte et al., 2012)
Global	While making economic growth resource-efficient and cleaner is feasible in the short term in some regions with strong policies, achieving it on a global scale in the longer term is very unlikely without green technology innovation.	(Hickel & Kallis, 2020)
Global	Green society is difficult to achieve as the GHG emissions are highly unequal, with the top 10% of the world population emitting 48% of the total, while the bottom 50% emitted only 12% in 2019.	(Chancel, 2022)
Global	Climate justice beliefs, for example, recognition of the disproportionate effects of climate change on poor populations and the foundational roles of capitalism and colonialism in driving the climate crisis, were widespread.	(Ogunbode et al., 2024)
Sub-Saharan Africa	Boosting food production for zero hunger (SDG 1), poverty eradication (SDG 2) and health promotion (SDG 3) may hinder renewable energy generation (SDG 7) and terrestrial ecosystem conservation (SDG 15) due to competition for water and land resources in Sub-Saharan Africa.	(Nilsson et al., 2016)
Asia	Burning coal to increase energy access (SDG 7) in Asian countries would emit massive GHG emissions and air pollution (SDG 13 and 14).	(Nilsson et al., 2016)
Europe	The green growth scenario, driven by technological advancements and environmental policies, could lead to a substantial decrease in GHG emissions but come with the drawbacks of rising income inequality and unemployment.	(D'Alessandro et al., 2020)
Europe	Greening cities enhances urban wellbeing and attractiveness, but the use of green strategies are primarily driven by markets targeting wealthier groups sometimes at the expense of less privileged residents.	(Haase et al., 2017)

Source: Collected by the authors

such as drought and diseases, so incorporating them into cropping systems can achieve not only zero hunger but more ecological goals (Meldrum and Padulosi, 2017) by reducing dependence on monoculture crops as well as enhancing diversification and adaptation (Padulosi et al., 2011). Genetic diversity is also valuable for conserving biodiversity and protecting species from extinction, especially in Asia and Africa (Will, 2008; Talucder et al., 2024).

Activating the strong sustainability of NUS does not necessarily rely on larger-scale production, but the utilization of NUS has been very limited because of constraints stemming from lack of public awareness, insufficient government support, and few research oriented programs (Bjarklev et al., 2019; Talucder et al., 2024) as well as price and quality issues (Pieterse et al., 2023).

Despite low utilization rates, there is growing evidence of potential market demand for consuming NUS. Health and nutrition benefits that drive people consume plant-based foods (Acquah et al., 2023) and besides local residents, urban consumers (da Cunha et al., 2020) and more mindful consumers are also attracted by NUS products (Sheth et al., 2010; Birch et al., 2018).

Existing literature has well documented the great potential of NUS in achieving one or two goals of SDGs, but not from economic, social and ecological perspectives. Table 2 lists case studies that focus on NUS across different regions. Most case studies offered empirical evidence on various barriers of adopting NUS value chains in economic lagging areas, yet few of them reported successful cases and summarized how to strategically create NUS value chains to achieve strong sustainability.

2.2. The barriers and drivers of NUS value chains adoption

Most documented NUS are from Asian and African developing

Table 2
Case studies of NUS across different regions.

Region	Main arguments	Source
Nigeria	In Nigeria, NUS play a crucial role in the diets of rural households, especially during droughts, famines, and dry seasons; Not limited to food security, NUS can be consumed by rural communities for health care, shelter, forage and fuel to alleviate poverty.	(Magbagbeola et al., 2010).
Brazil, Kenya, Sri Lanka, and Turkey	Due to their antioxidant, medicinal, and nutritional benefits, a rich diversity of NUS also help address malnutrition and improve health outcomes in vulnerable populations and potentially transform food systems in Brazil, Kenya, Sri Lanka, and Turkey, once diverse stakeholders establish strong coordination.	(Hunter et al., 2019)
Brazil	In Brazil, a number of urban gardens started to produce affordable food for the tradition of NUS cultivation and use.	(da Cunha et al., 2020)
Sri Lanka	NUS consumed by households in Sri Lanka came from either homegrown sources or wild harvesting and the processes of income generation from NUS remained overlooked.	(Bandula et al., 2016)
South Africa	Nostalgic connections between NUS and local cultural heritage could be a key consumption driver in South Africa.	(Pieterse et al., 2023)
Australia	Once integrating poor and marginalized populations into NUS value chains for poverty alleviation and ecological conservation, marketing strategies for NUS may potentially appeal to more "mindful" consumers who care themselves, communities and the environment.	(Birch et al., 2018; Sheth et al., 2010)
Asia	Farmers in China and Cambodia tend to significantly underestimate the value of NUS and overlook their exploitation potential.	(Schmidt et al., 2008)
Europe	A consumer survey conducted in six European countries showed that respondents have a neutral outlook towards consuming NUS, negatively affected by psychological barriers and positively motived by eating new food, environmental concerns, health and taste.	(Bayudan et al., 2025)
Mexico	Public policies in Mexico's Huasteca region have led to the neglect and abandonment of traditional food plant species. Their reintroduction through local culinary practices could strengthen agroecosystem resilience and food and nutritional security.	(Casanova-Pérez et al., 2024)

countries (Talucder et al., 2024), and implementing sustainable practices in remote rural areas, for example, adopting NUS value chains, is challenging. The sustainable livelihoods framework (SLF) highlighted five different types of resources, denoted by an asset pentagon, which are natural, human, financial, physical and social capital (Scoones, 1998). Yet, ineffective strategy and performance framework, short term goals (Kumar et al., 2021) as well as lack of inclusive institution interventions that push the region into virtuous circles of innovation and sustainable growth (Acemoglu and Robinson, 2012), hinder the utilization of local natural and human capital for sustainable practices.

About two-thirds of farmers are smallholders in the developing world, and nearly 98% of farmers cultivate farms smaller than 2 hectares in China (Rapsomanikis, 2015). According to the FAOSTAT database, rice, maize, wheat, soybean and potato are five major crops, occupying more than 90 % of China's total food production. A great number of smallholder farmers may face various predicaments in agriculture practices, including geographical remoteness and isolation (Bird et al., 2002), limited access to information, market, technology and finance (Phiri et al., 2019), lack of institutional support (Fitz and Gouri Suresh, 2021), low levels of education (Moock, 1981), aging (Ren et al., 2023), vulnerability to agricultural risks (Harvey et al., 2014) and dependence on agricultural machinery service providers (Chen and Jiao, 2024). These barriers intertwine with each other, hindering the economic well-being of smallholder farmers and trapping them in vulnerable, dynamic, and persistent poverty (Wang et al., 2021). More importantly, farmers in China and Cambodia tend to significantly underestimate the value of NUS and overlook their exploitation potential (Schmidt et al., 2008).

On one hand, insufficient capital in remote rural areas (Kumar et al., 2021), smallholder farmers trapped in poverty (Wang et al., 2021), and underestimated value of NUS (Schmidt et al., 2008) make it difficult to exploit those natural resources to create economic benefits. On the other hand, overexploitation, unsustainable collection and production practices may also pose challenges for NUS commoditization and biodiversity protection (Will, 2008).

Despites diverse barriers, once integrating poor populations into market systems as active participants (i.e., producers, entrepreneurs, employees, and consumers) can be achieved, they, different from aid-driven poverty reduction methods, are efficient and self-sustained, actively empowering the poor, and sustainably enhancing their income, resilience, and overall well-being (Ogutu et al., 2014; Jha et al., 2016; Li et al., 2019). Therefore, value chain analysis (VCA), from cultivation to production, to processing, to retailing and to consumption, is useful to understand dynamic factors that drive income growth and sustainable development (Kaplinsky and Morris, 2012; Manzoor et al., 2024).

Recent literature has shown that governmental planning and institutional interventions play a crucial role in adopting new value chains and improving rural livelihoods. The SLF emphasizes the institutional or organizational influence on utilization of natural and human capital and access to financial and social capital. Bjarklev et al. (2019) suggested a conceptual framework for NUS adoption in sustainable value chains and highlighted scientific and technological drivers as well as market drivers with the governmental interventions of push-pull policies. Therefore, institutions can not only promote investments in research and development (R&D) and partnerships (Hall et al., 2001), but also improve the information and communication technology (ICT) and logistics infrastructure in remote rural areas to overcome spatial divide and digital divide (Zhang et al., 2024).

2.3. ICT-driven sea buckthorn value chain

Sea buckthorn, used to be one of the NUS, is a resilient species native to Europe and Asia that can thrive in diverse harsh conditions, including extreme temperatures, drought, salinity, and poor soil (Li and Beveridge, 2003). The global sea buckthorn cultivation area is approximately 17300 km^2 with China accounting for the majority (Zhong et al., 2021). In China, the northwest is relatively underdeveloped yet rich in sea buckthorn natural stands (He et al., 2023; Meng et al., 2024). Specifically, the sea buckthorn resources are concentrated in Shanxi (33.64 %), Shaanxi (17.30 %), Gansu (14.42 %), Inner Mongolia (13.3 %), Liaoning (8.01 %), and Qinghai (7.93 %) (Zhong et al., 2021). Part of the reason is that back to the early 2000s, local communities and NGOs also planted more sea buckthorn to prevent deforestation or desertification and slow down sandstorms as it is notable in soil and water conservation, erosion control, and microclimate stabilization (Kang et al., 2017; La and García Guirao, 2020). In addition, the sea buckthorn berries, seeds, and leaves are also rich in bioactive and antioxidant compounds, making it a source of valuable derived products like juice and oil. The juice is known for its high vitamin C/E content for antioxidative effect and carotenoids for eye health (Ranjith et al., 2006; Andersson et al., 2009), while the oil, extracted from seeds or pulp, contains beneficial unsaturated fatty acids used in medicine and cosmetics, particularly palmitoleic acid (omega-7) good for epithelial tissues (e.g., digestive organs and skin), and phytosterols helping reduce the risk of cardiovascular disease (Ciesarová et al., 2020). Even the leaves can be used for tea infusions (Biel and Jaroszewska, 2017). Table 3 presents the nutritional and functional value of sea buckthorn, and Appendix A provides more detailed information about the components and associated functions of sea buckthorn.

The development of e-commerce has enhanced the online visibility and accessibility of sea buckthorn to a broader audience (Zhang et al., 2021). By 2019, over 122 million real trees were planted in desert areas

Table 3
Nutritional and functional value of sea buckthorn.

Attribute	Value	Ref.
Carbohydrates (*Monosaccharides, Polysaccharides*)	Sugars and sugar derivatives influence sensory properties.	(Jaroszewska et al., 2018; Solà Marsiñach and Cuenca, 2019)
Oil (*Palmitic acid, Palmitoleic acid, Stearic acid, Oleic acid, Linoleic acid, Linolenic acid*)	Palmitoleic acid is beneficial for epithelial tissues (e.g., digestive organs, respiratory, urological) and the inside of the eye (dry eye syndrome). Improve hydration and elasticity of the skin, reduce wrinkles and inflammation, and relieve skin burns when used in cosmetics.	(Mörsel, 2014; Suryakumar and Gupta, 2011)
Vitamin B (B_1, B_2, B_6)	Assists cell metabolism and synthesis of red blood cells.	(Zielińska and Nowak, 2017)
Vitamin C	Has some pharmacological effects in mucosa injuries, maintenance of membrane cell integrity, and as antioxidant.	(Solà Marsiñach and Cuenca, 2019)
Vitamin E (*tocopherols, tocotrienols*)	Offers protection against oxidative stress.	(Kallio et al., 2002)
Vitamin K	Helps wounds to heal	(Bal et al., 2011)
Flavonoids	Prevent and manage chronic diseases such as diabetes, cardiovascular diseases and/or cancer.	(Bal et al., 2011)
Tannins Phenolic acids	Bioactive and antioxidant properties	(Jones and Dangl, 2006; Ma et al., 2019)
Phytosterols	Associated with reduction of cancer incidence including cancers of the colon, breast, and prostate.	(Bal et al., 2011)
Carotenoids	Good for eye health.	(Bal et al., 2011; Pop et al., 2015)
Minerals *(Cu, Cr, Ca, Fe, Zn)*	Support a variety of metabolic processes	(Hussain et al., 2014)

Source: Adapted from Ciesarová et al. (2020)

of Northwest China through a so-called 'Ant Forest' project initiated by Alibaba that motivated users to walk, bike, use online payments and take public transportation, one of which was sea buckthorn, noted as its first edible product (Zhang et al., 2021). Meanwhile, local farmers can also obtain certain economic benefits by selling sea buckthorn juice on Alibaba's e-commerce platform. After this signature project, more and more e-commerce platforms have initiated their corporate social responsibility (CSR) projects and promoted rural products, including novel foods, online for poverty alleviation (Sen and Bhattacharya, 2001; Kwak et al., 2019; Fang and Huang, 2020; Zhou et al., 2021).

Technology innovation and adoption can contribute to the NUS adoption for poverty reduction and environmental conservation. Previous research has shown that the adoption of ICTs (i.e., e-commerce) can affect smallholder farmers directly through offering them enhanced access to markets, information, and resources that are previously out of reach (Ogutu et al., 2014; Kyaw et al., 2018) as well as reducing transaction costs and increasing expenditure savings (Rindfleisch and Heide, 1997; Faiz, 2012), and indirectly through enhancing their interactions with other stakeholders in agricultural value chains (Ruben, 2017; Ros-Tonen et al., 2019; Pan et al., 2023).

2.4. Literature gaps

Based on the discussions above, the following literature gaps are identified: (1) The importance of NUS adoption in achieving inclusive green growth at a region level under the framework of SDGs has not been widely recognized or prioritized; (2) Most case studies focused on challenges and barriers of adopting NUS value chains, but few of them learned from successful cases or identified key drivers of NUS adoption within a conceptual framework; (3) Although the e-commerce poverty alleviation (e-CPA) business models for income growth have been studied thoroughly, none of studies conducted in-depth interviews with stakeholders in agricultural value chains in China to explore how to use ICTs to benefit poor populations in remote rural areas.

3. Methodology

To understand how and why new NUS value chains are adopted as well as filling the literature gaps in this nascent research area where theories are not well-developed (Yin, 2009), qualitative methods are adopted to study the case of sea buckthorn.

3.1. Sampling

Three formerly NP counties, namely Huachi County, Zhang County and Weiyuan County, located in mountainous hilly areas in Gansu Province in northwest China are selected as our research site for three reasons. First, they are rich in NUS natural resources, and the substantial annual yield of sea buckthorn berries in these three counties is the foundation of the thriving sea buckthorn industry. Second, they used to be poverty-stricken and the rural population in these remote areas were trapped with limited access to information, technology, and markets. It is challenging for them to pursue sustainable development and establish new value chains. Third, these three counties have been developing the local sea buckthorn industry for over a decade with at least one established enterprise, generating decent economic value with e-CPA interventions.

To analyse the sea buckthorn value chain comprehensively, this study identified six key stakeholder groups through existing reports and consultations with local experts: (1) berry pickers, (2) brokers, (3) local enterprises, (4) retailers, (5) consumers, and (6) government officers. Stakeholders were selected via purposive sampling to capture the diverse perspectives and roles within the value chain. This research particularly targeted the leading sea buckthorn company in the region and interviewed senior managers, technical directors, processors, packers, and salesmen to understand production, processing, and marketing strategies. The local government officers working in the agriculture and commerce-related departments were also contacted to analyse institutional support of technology-push and market-pull policies toward the local sea buckthorn industry. The researchers also had connections with the largest broker through consulting the employees of the largest sea buckthorn company in these three counties. As for berry pickers, retailers, and consumers, our sampling strategy focused on stakeholders of different demographic and socioeconomic backgrounds and selected a few to ensure representation across these groups.

Table 4 presents the demographic information of the interviewed stakeholders. Given the fact that picking up and processing sea buckthorn berries is a physical work and rural out-migration for higher-salary jobs results in aging of rural population (Chen et al., 2014; Qin and Liao, 2016), the majority of the interviewees are males aged over 40. Appendix B specifies the ID, demographics and role of each interviewee.

3.2. Data collection

Data gathering involved collecting data from government and media reports and industry data before the site visits as well as conducting face-to-face interviews and making observations during the site visits in three counties using a semi-structured guide equipped with open-ended questions, designed before the data collection commenced to ensure guidance and consistency across interviews. Appendix C presents the interview questions. The interviews are in Mandarin Chinese and occasionally need interpretation when pickers only spoke the local dialect. Although the guide was structured, flexibility was allowed to let participants elaborate on topics within their expertise. The researchers also asked some follow-up questions to explore incidental findings during each interview if necessary. All interviews were recorded and transcribed into more than 27,000 words. Ethical approval for the interviews was secured from a University's Research Ethics Committee. Besides interview transcripts, the types of collected data include field notes, photos, governmental documents and media reports. Most of the site visits occurred in August 2023, but the researchers took a few photos during the sea buckthorn harvest season in early October. To reach data saturation, the researchers stopped interviewing new pickers and

Table 4
Demographic profile of study participants.

Role	Professional status	Gender	Age	Num
Berries Picker	Harvest berries from wild mountains for revenue, and sell to brokers or enterprises	Male	40–50	2
			50–60	6
			60–70	1
		Female	50–60	1
Broker	Buy from pickers, pre-process, pack, store, and sell to local or non-local companies	Male	30–40	1
			40–50	3
			50–60	2
Enterprise	Work as CEO, technical director, processor, saleswoman, or delivery packer to process, manufacture, pack, market offline/online, or manage	Male	20–30	1
			30–40	3
			40–50	5
		Female	30–40	1
Retailer	Operate house farms, restaurants, or souvenirs stores, and do marketing and sell to tourists	Male	30–40	1
		Female	40–50	2
			50–60	2
Consumer	Consume sea buckthorn juice, seed/pulp oil, or both	Male	20–30	3
			30–40	2
			40–50	2
			50–60	1
			70–80	1
		Female	20–30	3
			30–40	3
			40–50	2
			50–60	1
Government Officer	Work at Agriculture and Rural Affairs, Commerce Affairs, or county/town-level governments	Male	40–50	8
			50–60	1
		Female	30–40	1

consumers until no new themes emerged from the interviews. The total sample size comprised 59 participants, in line with previous recommendations of a minimum sample size of at least 12 to reach thematic saturation (Fugard and Potts, 2015).

3.3. Data analysis

To reduce bias issues, this research followed the principle of triangulation (Yin, 2009). First, the researchers collected existing government and media reports and industry data to complement interview and field observation data. Second, the researchers conducted site visits in three different counties twice to double-check whether claims were consistent over time. Third, the researchers created a database to manage all collected data together using NVivo 12 software. Fourth, the researchers made an effort to identify chains of evidence and substantiate the claims by echoing one piece of evidence with another.

Data processing focuses on thematic analysis (Braun and Clarke, 2013; Guest et al., 2011; Nowell et al., 2017) aimed at exploring the perspectives, values, experiences, and behaviours of stakeholders within the sea buckthorn value chain. Repeated reviews of the transcripts facilitated the identification and coding of diverse themes that addressed the research questions. These initial codes were later synthesized into broader themes that encapsulated the data more accurately, revealing SWOT specific to certain stakeholders and key factors influencing the adoption of the sea buckthorn value chain. The themes were interconnected across different phases of the sea buckthorn value chain to deepen the understanding of the roles of institutions, ICTs, and the collaboration of stakeholders in benefiting poor rural populations, growing local economy, and improving environmental resilience. This study established the conceptual framework for NUS value chain adoption step by step based on evidence and their chains and compared our findings with the existing literature and theories in sustainable agriculture and VCA iteratively until reaching theoretical saturation.

4. Results

This section presents the main findings for each type of stakeholder in the value chain.

Fig. 1 presents the main themes and subthemes for data analysis. To evaluate how to establish a new NUS value chain, this study identifies four key drivers due to push-pull strategies by local governments, financial institutions, and e-commerce companies for new value chain adoption. To analyse how to benefit local communities sustainably, especially marginalized populations, this research introduces the role of each type of stakeholders and conduct a SWOT analysis for value chain stakeholders based on theories of SLF and VCA. To analyse the role of NUS in promoting strong sustainability, the researchers compare the differences before and after the adoption of the sea buckthorn value chain and couple these positive outcomes with economic, social and environmental objectives of the SDGs. By investigating the case of sea buckthorn, this study deepens the understanding of how to facilitate collaborations among stakeholders to utilize NUS responsibly for sustainability. Overall, the study has three main themes and eleven subthemes of data analysis.

4.1. Pickers

Sea buckthorn berries, like most NUS, grow wild under natural conditions in arid mountains with sparse vegetation, which require no additional cultivation or maintenance. The pickers of sea buckthorn

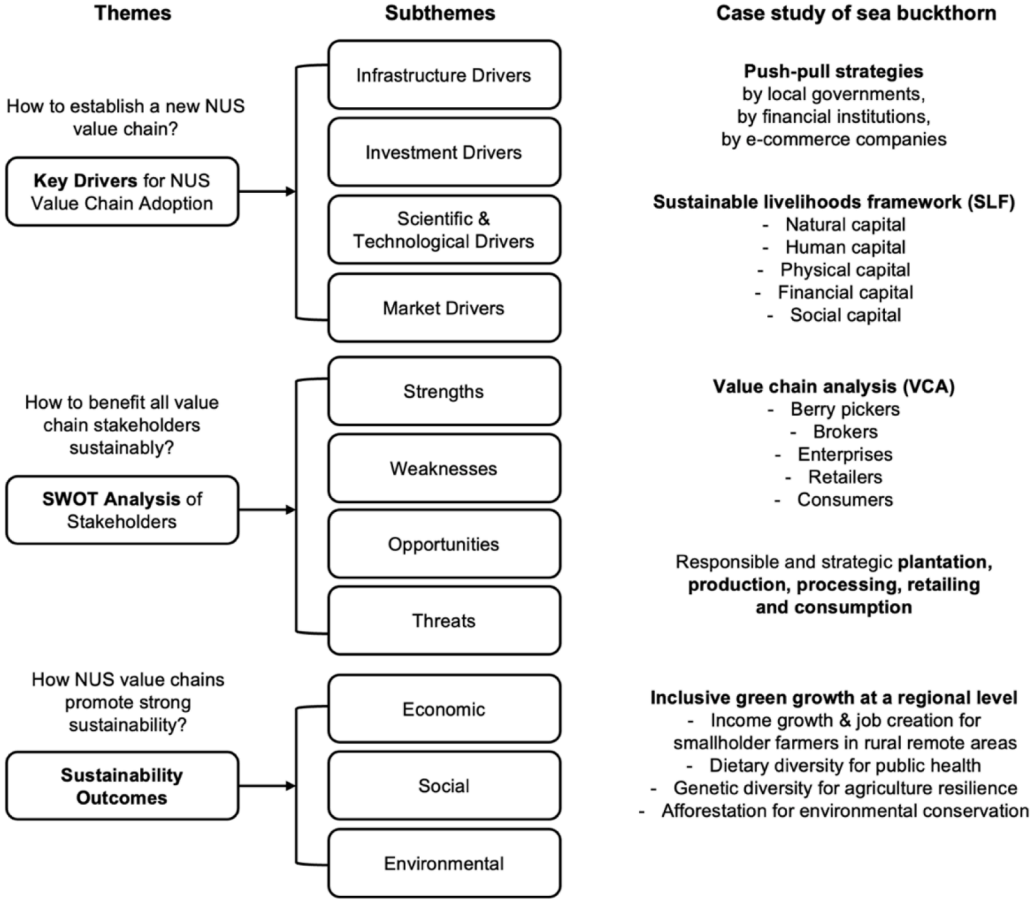

Fig. 1. Themes and subthemes of data analysis.

berries, mainly smallholder farmers, are the first link in the entire value chain of sea buckthorn.

The pickers we interviewed started to work on this around five years ago. Before this, there was a lack of market demand, and they only picked some to consume themselves. At that time, internal natural capital (sea buckthorn) and human capital (rural poor populations) were not fully utilized to create economic value. Sea buckthorn is only valued by its environmental benefits such as preventing soil erosion and deforestation. Its nutritional and economic value has been overlooked.

With the development of the local sea buckthorn industry, more locals have taken advantage of the opportunity to earn extra income by harvesting sea buckthorn berries between mid-September and mid-October. They have no contractual relationship with any companies, and work seasonally and flexibly, as everyone can get access to open mountainous areas during harvest seasons. This new seasonal job opportunity created by adopting new sea buckthorn value chains has empowered poor households in remote rural areas and improved the local economy; the economic value of both natural and human capital has been properly utilized.

Harvesting small sea buckthorn berries is a labour-intensive work and consumes great physical energy. Instead of shaking trees with larger berries in Xinjiang Province, the pickers in these three counties must push carts or carry bamboo baskets, walk on the mountainous roads, and wear gloves to hold spring-loaded shears to prune branches laden with berries. They often start with the mountains on the outskirts that are accessible and when they go deeper, the difficulty of harvest increases with outdated picking and transport methods. It takes about a week for a fresher to become a proficient picker, so the harvest speed during the first week of each season is normally slower as pickers need to practice. However, young adults from rural areas tend to migrate to urban areas and work for stable salaries and children cannot protect themselves well from dangerous pruning shears, so people in their 50s and in good health are the main sea buckthorn pickers. A picker in his 50s shared his view:

> *"It is more of a rotating system, where younger people may leave for work elsewhere but return to participate in harvesting (sea buckthorn berries) as they get older." (Source: P29[2])*

This indicates that urban-rural labour migration is essential to mitigate the issue of the ageing rural population and provide sufficient human capital sustainably in these three counties.

An efficient market attracting a certain number of buyers delivers negotiating power to pickers; A competitive market price incentivizes more smallholder farmers to participate in harvest activities. Currently, pickers can sell berries to two types of buyers in the value chain: (1) brokers that sell pre-processed berries to enterprises and (2) enterprises that use a more advanced processing system to produce juice, oil and other derivative products. The purchase price offered by brokers and local enterprises is 2–3.6 yuan[3] per kilogram of berries attached to small branches. This reasonable price ensures that the daily income from harvesting sea buckthorn (above 200 yuan per day) is higher than that from other laborious jobs (150–160 yuan per day). Although sea buckthorn processing enterprises are willing to pay a slightly higher price, pickers prefer to sell berries to brokers for two reasons. First, brokers are often neighbours or acquaintances of the pickers. They purchase berries directly at the foot of the mountains and pay in cash on the spot. Second, most pickers do not have their own cars, and their three-wheeled vehicles are prohibited on public roads for road safety, thus it is costly for them to transport berries to the location of enterprises whose distance is far from their homes.

Theoretically, an experienced picker could earn roughly 250 yuan per day and 7500 yuan per year. Practically, the income growth achieved by sea buckthorn harvesting varies widely due to differences in diligence, skill, and berry quality, as buyers inspect the berries and may discount prices if the proportion of berries to attached branches fails to meet certain standard. Based on estimates from local sea buckthorn companies, the annual household income of pickers has increased by 3000 to 4000 yuan on average. Therefore, the lack of jobs hinders the improvement of sustainability in rural remote areas; once a new NUS value chain is adopted, rural poor populations can more or less benefit from engaging in value chain activities and earning extra income.

Unlike large-scale cash crops production, the responsible use of sea buckthorn must consider unique characteristics of NUS and adhere to ecological principles. The growth and maturity of sea buckthorn berries is subject to cyclical fluctuations (one "big" harvest year followed by three "small" years). During the big year, harvesting is relatively easier. In small years, pickers harvest fewer berries, and local enterprises may purchase from other places to secure sufficient supply.

To expand the sea buckthorn industry and reduce difficulty of harvesting, local governments and enterprises are collaborating to implement terraced planting on barren hills. This initiative not only simplifies harvesting for pickers but also supports reforestation efforts and encourages greater public participation in planting sea buckthorn for environmental conservation. This highlights the importance of strong institutions and partnerships between value chain stakeholders, particularly governments, enterprises, and local communities.

4.2. Brokers

The local agricultural brokers have long-standing experience in connecting farmers with processing enterprises. As more and more people recognize the poverty alleviation, environmental, and nutritional benefits of sea buckthorn products nationwide through the internet, brokers also have grown their profits by purchasing berries from pickers, doing basic processing, and selling to larger brokers or enterprises with a more advanced processing system.

Brokers play an indispensable role in the sea buckthorn value chain for three reasons. First, brokers gain trust among locals easier as they build closer connections with local communities. Second, most pickers face transportation and storage issues, while small brokers go to the mountains to make purchases every day during the harvest season, so pickers can receive instant payments. Third, they inspect the quality of the berries and absorb some risks of low-quality berries. A small broker in his 40s said,

> *"Sometimes, some people pick berries that do not meet the requirements. If I did not notice it during the purchase, I could only consider it bad luck." (Source: P6)*

Local brokers have established a social network, as they are not only competitors but also cooperation partners. They all buy berries from pickers, but larger brokers can also purchase from smaller brokers and focus more on basic processing, including separating the seeds from the pulp and processing the pulp into puree. The processed sea buckthorn products are easy to store or transport. The added value from basic processing is satisfying for both small and large brokers as they indicated that they would continue working in the sea buckthorn industry in the near future.

However, even large brokers feel it difficult to upgrade their processing system as they cannot afford a very high fixed cost (around 600,000 yuan) of seed oil processing system which local enterprises equip. In addition, most brokers in rural areas are in their 50s, and they lack knowledge of digital technologies, hence operating online stores and marketing through e-commerce is challenging for them.

In the long run, the establishment of sea buckthorn enterprises may squeeze the living space of brokers. However, in the short term, local brokers with stronger ability to gain trust from pickers and access potential clients through personal connections are still growing income from engaging in sea buckthorn value chain activities. This indicates

[2] P29 refers to the interview participant indexed by P29 (see more details in the Appendix B). Same as mentioned later in the text.

[3] 1 Chinese Yuan = 0.14 US Dollar (updated in January 2025)

that besides natural, physical, and human capital, social capital also plays a crucial role in adopting NUS value chains and facilitating strong collaboration among stakeholders.

4.3. Enterprises

ICTs, particularly e-commerce, can be seen as a key driver to attract external financial capital to invest in the local sea buckthorn industry. The local sea buckthorn processing enterprises are expanding their businesses through both online and offline sales channels in front of growing consumer demand and public interest in sea buckthorn products largely driven by major Chinese e-commerce companies. The leading sea buckthorn enterprises in the three counties were established in 2010, 2012, and 2014 respectively, aligning with the rapid rise of e-commerce in China.

With the boom of the internet, the development of the local sea buckthorn industry is promising as these sea buckthorn processing enterprises have established sustainable profit models in the business-to-business (B2B) and business-to-consumer (B2C) sector. Specifically, the sea buckthorn processing enterprise in Wei Yuan County has achieved an annual asset growth rate of 35 % and produced a variety of sea buckthorn products, including sea buckthorn puree, seed oil, fruit oil, candies, and beverages. A majority of processed products are supplied to large clients, for example, state-owned medicine enterprises, but individual consumers who mainly make online purchases through e-commerce contribute to a higher profit margin.

Growing investments contribute to technology innovation, improvement of supporting facilities and services, as well as standardized production for improving product quality and meeting higher market standards. With more financial capital flowing into the sea buckthorn industry, the local sea buckthorn enterprises can afford the advanced processing equipment for pulping, separation of fruit oil, sterilization, canning, and extraction of seed oil. The added value of seed oil is the highest, but the fixed cost of the seed oil extraction equipment is also high. The upgrade of physical capital is essential for these enterprises to create higher added values.

These processing enterprises also received support from both local governments and financial institutions. In particular, local governments provide targeted subsidies, awards, special funds, and other incentives to support agricultural enterprises. The public investment in rural road infrastructure has improved the logistics system to overcome the last-mile delivery challenge, and in the meantime improve the efficiency and value of land use. The CEO of a sea buckthorn company said,

> *" In the past, the location of the factory was just barren land. But then, they improved the rural roads, which allowed them to build the factory here." (Source: P20)*

In addition to preferential policies, financial institutions also have streamlined the financing process for small and medium enterprises (SMEs), reducing both time and costs. Banks offer the "See Guarantee, Get Loan" option to SMEs and complete the loan disbursement more quickly after a formal review of loan application materials, especially the business guarantee letter from the guarantee company. This has allowed enterprises to secure funding efficiently and constantly attract internal and external financial capital to expand their business.

To continue increasing added value and attract potential clients in both domestic and overseas, these companies realized the importance of brand cultivation and reputation. As small sea buckthorn berries in Gansu have a higher oil content suitable for making fruit oil and seed oil whose nutritional value is higher than that of juice, they put "Zhang County, Hometown of Sea Buckthorn" on the packaging of their products as a geographical indication and applied for quality certification, such as the organic certificate and the trademark "Drink More Sea Buckthorn".

Although e-commerce platforms create numerous opportunities, SMEs still need to be cautious about the selection of online marketing approaches. The first attempts at live-streaming sales and online advertising of these enterprises have not been very successful. A company invested 2 million yuan but did not receive much return. The main issues were the lack of influential live-stream anchors and the high costs of hiring such talent. Meanwhile, intense competition forced companies to lower profit margins and offered low-price offers to attract audience in the live broadcast room, further limiting profitability. Consequently, these enterprises started to seek cooperation opportunities with influential livestreaming accounts and platforms instead of operating the livestreaming channels on their own. This indicates that only accumulating more human and social capital can further optimize marketing strategies and cultivate reputational brands.

Even with these challenges, these sea buckthorn processing companies have greatly contributed to job creation, poverty alleviation and income growth. The CEO of a sea buckthorn processing enterprise said during the interview,

> *"The company has employed more than 40 registered impoverished households with an annual fixed salary of 1.6 million yuan and hired over 8,000 seasonal workers with a total seasonal wage payout of 300,000 yuan." (Source: P4)*

4.4. Retailers

Local retailers, including specialty agricultural product stores, restaurants, and agritainments, are willing to promote and sell sea buckthorn products not only because the unique taste and rich nutrition of sea buckthorn products help consumers gain new dietary experience and achieve more sales for retailers, but also because they hope to support the local business and the local specialty products with cultural and public welfare attributes. In the sales process, they would use the place of origin and its high nutritional value as the selling points and may tailor the promoting techniques by collecting customer feedback on product experience and differentiating different age groups. The owner of a local specialty agricultural product store said,

> *"For younger consumers, I would recommend sea buckthorn juice and puree, with a bottle of sea buckthorn juice priced at 7 yuan, whereas for older consumers with stronger spending power, I more often recommend boxed sea buckthorn fruit oil (198 yuan) and seed oil (298 yuan), the latter having a larger profit margin." (Source: P27, echoed by P54 and P56)*

Although sales remain primarily offline, some specialty stores have begun exploring online channels, including live streaming, which accounted for about 20% of revenue for one retailer we interviewed in her first year. Despite mixed results from online efforts, retailers see long-term potential in e-commerce as consumer preferences shift toward online shopping.

Before the creation of the sea buckthorn value chain, these retailers primarily focused on selling staple local agricultural products. They are experienced and have strong control over local sales channels. On the one hand, they understand the absolute advantages of each product as well as the relative advantages of local products compared to those from other regions. On the other hand, they often have an accurate grasp of consumer psychology and preferences. As a result, in the context of the local market, retailers act as effective market drivers, capable of marketing quality products to suitable consumers. Tourists from all over the country can experience the consumption of sea buckthorn products in these three counties, thus reinforcing brand recognition and market demand.

With the popularity of refined sea buckthorn products, these retailers can now play a significant role in promoting sea buckthorn not only in person but also online. The retailers we interviewed do not face significant challenges in selling sea buckthorn products, as inventories can be sold out quickly. They are optimistic about future growth, particularly through online sales channels, and continue to learn and adapt to digital

marketing trends.

4.5. Consumers

Consumers of sea buckthorn products span a wide range of age groups, from 7 years old to over 70. They got to know sea buckthorn products through social media, e-commerce platforms, word of mouth, and local stores in Gansu Province during travels.

The sea buckthorn juice, valued for its high vitamin C content, appeals to a wider consumer base compared to sea buckthorn oil primarily consumed by the elderly for cardiovascular health. Although most consumers are not fully aware of the nutritional and functional value of juice and oil, the function of boosting the immune system made the sea buckthorn juice popular, especially during the pandemic.

Besides health benefits, product quality and brand reputation enhanced consumer trust, recognition and loyalty. Two consumers explained why they purchased the products,

> *"I previously researched and found out that Zhang County is the hometown of sea buckthorn. […] The sea buckthorn concentration in juice is over 40% in this company, while most other companies are around 30%." (Source: P31)*

> *"I had heard about the founder of this sea buckthorn enterprise and his inspiring story before. It seemed quite legendary and touching. Moreover, the fact that he was willing to put his own image on the packaging made me feel that he had great confidence in his own product." (Source: P52)*

ICT adoption also enables the market-pull strategy and accesses more social capital as more and more socially responsible consumers started to be aware of multi-benefits of sea buckthorn products. A young sea buckthorn juice consumer also shared her experience,

> *"When I planted virtual trees in my Alibaba Ant Forest app, I remembered a pop-up window for Alibaba's e-commerce platform advertised sea buckthorn juice. Since I found I could help locals in rural areas to improve their life, I decided to buy." (Source: P33, echoed by M12)*

However, the taste preferences of consumers vary. Many consumers enjoy the sour-sweet flavour of sea buckthorn juice, finding it refreshing and beneficial for digestion. Some find the juice too sweet or astringent, while others consider the puree too sour but prefer it for its natural and healthy qualities. Therefore, sea buckthorn processing companies may need to do more market research and collect sea buckthorn feedback to adjust the sugar/acid ratio for different products and improve the sensory experience.

The increasing market demand attracts more investments in the local sea buckthorn industry, thus supporting more scientific research for breeding and taste innovation as well as promoting job creation for poverty reduction and income growth. Although the health benefit of sea buckthorn products is the main consumption driver, its social and environmental benefits can also be advertised to attract more mindful consumers and increase brand recognition.

4.6. Government officers

The government officers interviewed coordinate and focus on sea buckthorn research and development (R&D), agricultural development, commerce and economic development, and public welfare.

The Sea Buckthorn Research Institute, established in 2006 under the guidance of the Ministry of Water Resources, has been promoting the cultivation of sea buckthorn in mountainous areas plagued by severe soil erosion. This initiative aims to protect the environment, control erosion, and increase green coverage on barren hills. The chosen species, Chinese sea buckthorn (*Hippophae rhamnoides* subsp. *sinensis* Rousi), was selected for two primary reasons: its low seedling cultivation costs and its high survival rates, which require no maintenance. For Wei Yuan County, the local government has assisted in planting a total of 340,000 square hectares of sea buckthorn mainly due to its ecological value; The economic value of sea buckthorn has not been recognized until 2012, when the first sea buckthorn processing company was founded. For Zhang County, it was officially designated as the "Hometown of Chinese Sea Buckthorn" by the China Special Products Promotion Committee in July 2011 and received the national geographical indication protection certificate in 2020 for its small-berry sea buckthorn variety. For Huachi County, it has a long history of producing fruit beverages, including sea buckthorn juice, but the extensive land clearing and grazing in the 1990s made the sea buckthorn forest area decline and the local sea buckthorn industry disappear. The local government initiated three major forestry and ecological projects to revitalize the local sea buckthorn planting and commercialization.

The plantation of sea buckthorn requires scientific evidence. The Sea Buckthorn Research Institute applied tissue culture techniques to propagate female plants to ensure the breeding of high-quality female plants and maintain the right male-to-female ratio. The ratio is typically around 1:8, meaning one male plant (better at erosion control but grow no berries) can pollinate eight female plants (grow berries) within a specific area. In addition, planting sea buckthorn on flat land is prohibited. The local government and enterprises will implement terraced planting in the future to ensure that sea buckthorn will not occupy arable land for farming activities. Importantly, the harvest follows a big year with a great number of grown berries and three small years with relatively lower production. It requires the establishment of cooperation and trade networks across different counties to achieve a stable supply.

Over the past decade, the local government promoted industry-based poverty alleviation by enhancing the quality of local specialty industries. They selected a group of agricultural industries with local characteristics, providing them with policy and financial support to refine and upgrade their production chains. This effort includes cultivating more farmers, increasing the number of participants in the value chain, and enhancing its specialization to boost employment. By producing higher quality agricultural products, sales volumes can be increased, thereby raising the income of the participants.

During this process, local governments provide multi-faceted policy interventions to expand the local agricultural industry through logistics and ICTs. First of all, these three counties all have started to receive specialty funds to improve road infrastructure and develop rural e-commerce associated with surging investment in local specialty industries. Appendix D presents the amount of government specialty funds for these three counties during 2012–2023. Specifically, they support the transformation of traditional enterprises by offering economic incentives to design public brand trademarks, subsidizing cross-border trade, processing and packaging, same-city delivery, and online store operation. In addition, they set rewards for brand certification, e-commerce promotion, short video marketing, and live streaming base construction. Last, but not least, they connect local people with larger companies in other provinces to attend rural product exhibitions and e-commerce training programs. These interventions have incentivized the local agricultural enterprises and cooperatives to increase market access, accumulate human capital, shorten the supply chain, and target a larger group of consumers.

While the major agricultural products that have received much stronger policy support are potatoes and traditional medicinal herbs, the local sea buckthorn industry, as one of the local agricultural industries, has also benefited from these governmental policies. Both the technology-push policies (e.g., R&D investment, breeding/planting techniques), and the market-pull policies (e.g., e-CPA subsidies), contribute to the creation of key drivers and the utilization of natural capital (e.g., sea buckthorn), human capital (e.g., smallholder farmers), physical capital (e.g., processing equipment) and social capital (e.g., online consumers) as well as financial capital. Accordingly, the "picker-broker-enterprise-retailer-consumer" value chain has actively engaged locals in rural remote areas to interact with each other to generate additional income, reduce inequalities, sustainably achieve economic

growth and participate in ecological protection.

Table 5 presents the SWOT analysis for each type of value chain stakeholder. It is clearly observed that the "picker-broker-enterprise-retailer-consumer" value chain has actively engaged locals in rural areas to interact with each other to generate additional income and sustainably achieve local economic growth as well as ecological protection with the help of institutions and ICT adoption.

5. Discussion

The research reveals that NUS can represent a promising strategy for sustainable development, particularly in remote rural areas. The findings of this case study contribute to filling the literature gap and answering our research questions.

First of all, a nuanced understanding of how to establish new NUS value chains was uncovered to benefit local communities under a holistic framework. Fig. 2 presents the key drivers for mobilizing capital to establish the sea buckthorn value chain to achieve SDGs.

For scientific and technological drivers, sea buckthorn has been researched as a suitable species for afforestation due to its low seedling cultivation costs, high survival rates and minimal maintenance costs. Then, sea buckthorn berries and leaves have been found valuable during research as they can be processed to produce sea buckthorn puree, seed oil, fruit oil, candies, and beverages. More recently, the scientific evidence provided more guidance on terraced plantation, male-to-female ratio, and harvest year cycle to scientifically plant and harvest sea buckthorn. In addition to mastering scientific knowledge, the leading sea buckthorn enterprises have equipped advanced processing systems to increase added values and produce a greater variety of products. Correspondingly, the improved product diversity and quality has helped cultivate brand reputation and more loyal customers. The e-commerce training programs for online advertising and online store operation, as well as the attendance of agricultural product exhibitions have also facilitated the accumulation of human capital to adopt the technology scientifically.

When it comes to market drivers, the local government has utilized ICTs, particularly e-commerce, to allow sea buckthorn products to access a larger market and raise public awareness of the economic, ecological, nutritional and poverty reduction benefits of sea buckthorn. The digital technological adoption by local enterprises and the assistance from large e-commerce companies have expanded both offline and online sales channels, thus increasing visibility among consumers in the market. Meanwhile, the improved road and logistics infrastructure supported by the local government enabled online shopping and package delivery between remote rural areas and urban areas, thus promoting rural employment and agricultural industry development. To further drive market expansion, the enterprises have also put efforts into registering quality certificates and designing impressive trademarks with cultural attributes, thus increasing trust among consumers and then repurchase rates.

The findings are consistent with the view of Bjarklev et al. (2019) that government planning and participation is important to support push-pull policies; scientific and technological drivers and market drivers are important to create new value chains. Yet, our study further suggests these two drivers can interact with each other and have synergic benefits. On the one hand, technology adoption and scientific discoveries have contributed to expanding sales channels and increasing trust and credibility among consumers. On the other hand, the increased market demand through digital marketing has also motivated local sea buckthorn enterprises to invest more in R&D and processing equipment. During this process, corporates conducting CSR activities and consumers valuing positive environmental and social impacts of corporates play an

Table 5
The SWOT analysis for each type of value chain stakeholder.

Role	Positive Outcomes	Strengths	Weaknesses	Opportunities	Threats
Pickers	1. Local impoverished households are integrated into the value chain; 2. Additional income through increased job opportunities.	1. Physically capable; 2. Available spare time; 3. Relatively low labor costs in rural areas.	1. Outdated picking and transport methods; 2. Some workers lack discipline.	1. Terraced planting of sea buckthorn in barren hills will reduce picking difficulty and physical effort.	1. Fluctuating harvest yields over years; 2. Severe aging issues of rural population.
Brokers	1. The development of local industry and value chains leads to more orders and income.	1. Rich experience in purchasing and reselling of crops; 2. Local connections and procurement channels, easy to gain trust; 3. Own trucks capable of transporting sea buckthorn on rural roads.	1. Limited capital investment restricts upgrading of processing equipment.	1. Establish more local partnerships to enhance trust.	1. Potential replacement by modern enterprises.
Enterprises	1. Increased demand for sea buckthorn products leads to higher income and profits; 2. Created jobs for smallholder farmers; 3. Prevent soil erosion and deforestation.	1. Benefits from government policies and e-commerce training; 2. Reduced financing costs; 3. Afford advanced processing and packaging equipment; 4. Increased brand recognition and added values.	1. Limited online influence and visibility of local enterprises; 2. High advertising costs; 3. Intense price competition on live-streaming platforms.	1. Abundant local quality sea buckthorn resources; 2. Apply for organic certifications to attract more business clients.	1. Competition with larger and more influential enterprises from other regions.
Retailers	1. Promote hometown specialties; 2. Increased income.	1. Rich experience in sales techniques and models; 2. Precise targeting of sales demographics.	1. Small local market, limited number of consumers covered.	1. Develop e-commerce; 2. Collect customer feedback on product experience.	1. A diverse product range with sea buckthorn as a minor and well-performing product, so no major threats.
Consumers	1. Access to new specialty products with local characteristics; 2. Enrich dietary diversity; 3. Intake of beneficial natural & health elements.	1. Feel convenient to shop online and get parcels at home; 2. Increasing consumers' demand for improving health.	1. Not fully aware of the nutritional and functional values of sea buckthorn.	1. Attract more socially responsible consumers; 2. Adjust the sugar/acid ratio to increase sensory quality.	1. More expensive than apple/orange/grape juice; 2. Limited market access compared to other juice.

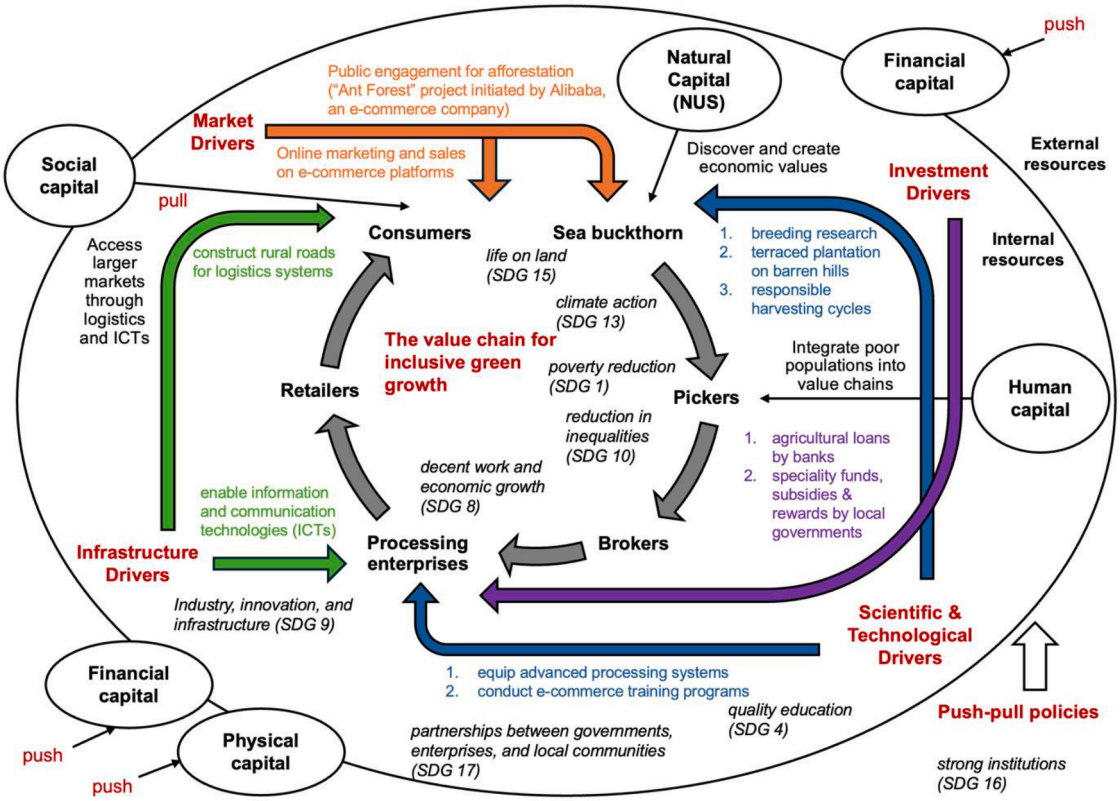

Fig. 2. Key drivers for adoption of sea buckthorn value chain to achieve SDGs.

important role in creating more local jobs for sea buckthorn harvesting and planting more sea buckthorn trees. Different from Bjarklev et al. (2019), we highlight the importance of two more drivers, namely infrastructure and investment drivers, in shortening physical/social distance between rural areas and urban areas and stimulating R&D investment.

Furthermore, to integrate marginalized populations into NUS industries with inclusive value chains, this paper novelly proposes a package of push-pull strategies that can coordinate well to dynamically integrate science, technology, funding, infrastructure, and social network into each part of the value chain for responsible plantation, production, processing, marketing, and consumption. In the case of sea buckthorn, smallholder farmers as pickers, brokers, small entrepreneurs and retailers in local communities have all benefited from increasing market demand for sea buckthorn products and emerging local job opportunities with extra income. The external financial, physical, and social capital driven by CSR initiatives by ICT companies and institutional support contributes to the activation and utilization of internal natural and human capital that used to be overlooked.

However, sustainably benefiting all stakeholders with inclusive NUS value chains is still challenging. From the supply side, the harvest yields have been fluctuating over years, destabilizing the annual income of berry pickers; Aging rural populations have been a more severe phenomenon, so the sea buckthorn harvesting relies on population migration from urban to rural areas. To compete with larger and more influential sea buckthorn enterprises, local sea buckthorn firms need to constantly improve the product quality and brand reputation to attract more clients. From the demand side, sea buckthorn juice is more expensive yet less visible compared to other types of juice (e.g., apple, orange, grape), and the price of sea buckthorn oil is even much higher than that of juice. Fortunately, the unique characteristics of NUS make it difficult to practice large-scale farming, so the limited supply and the high nutritional and functional value may enable the announcement of good-quality products targeting high-end consumers in niche markets.

Last, but not least, the findings also contribute to the existing literature by demonstrating how NUS can simultaneously address economic, social, and ecological inclusiveness, thereby challenging the prevalent notion of trade-offs between different SDGs. The case of sea buckthorn highlights the role of industry, innovation, and infrastructure (SDG 9), strong institutions (SDG 16), partnerships between governments, enterprises, and local communities (SDG 17), and quality education (SDG 4), in promoting protection of poverty reduction (SDG 1), decent work and economic growth (SDG 8), reduction in inequalities (SDG 10), life on land (SDG 15) and climate action (SDG 13).

The underrepresentation of ecological and relational inclusiveness in both the SDGs and initiatives like the RITII suggests a need to rebalance priorities in sustainable development; NUS in some contexts indeed contribute to inclusive green growth without sacrificing ecological goals for economic and social goals. Consistent with Hall et al. (2001), our study shows that collaborative efforts between local governments, enterprises, and local communities in using the wild sea buckthorn and implementing terraced planting of new plants will encourage broader community participation in environmental conservation. Our research also substantiates the potential of NUS in supporting ecological resilience. Sea buckthorn's ability to thrive in harsh conditions and contribute to soil conservation aligns with Talucder et al.'s (2024) observations about NUS's potential for ecological sustainability. The terraced planting initiative represents a practical approach to reforestation and environmental management, showcasing how agricultural development can simultaneously serve ecological goals. This study then proposes a conceptual model for adopting NUS value chains to achieve inclusive green growth in Fig. 3.

Our findings align with and extend the existing literature on inclusive growth (Aslam et al., 2020). The sea buckthorn value chain has created employment opportunities for rural populations, particularly berry pickers in their 50s and 60s. The ability to earn an additional 3,000 to 4,000 yuan annually through seasonal harvesting represents a significant income enhancement for households in economically

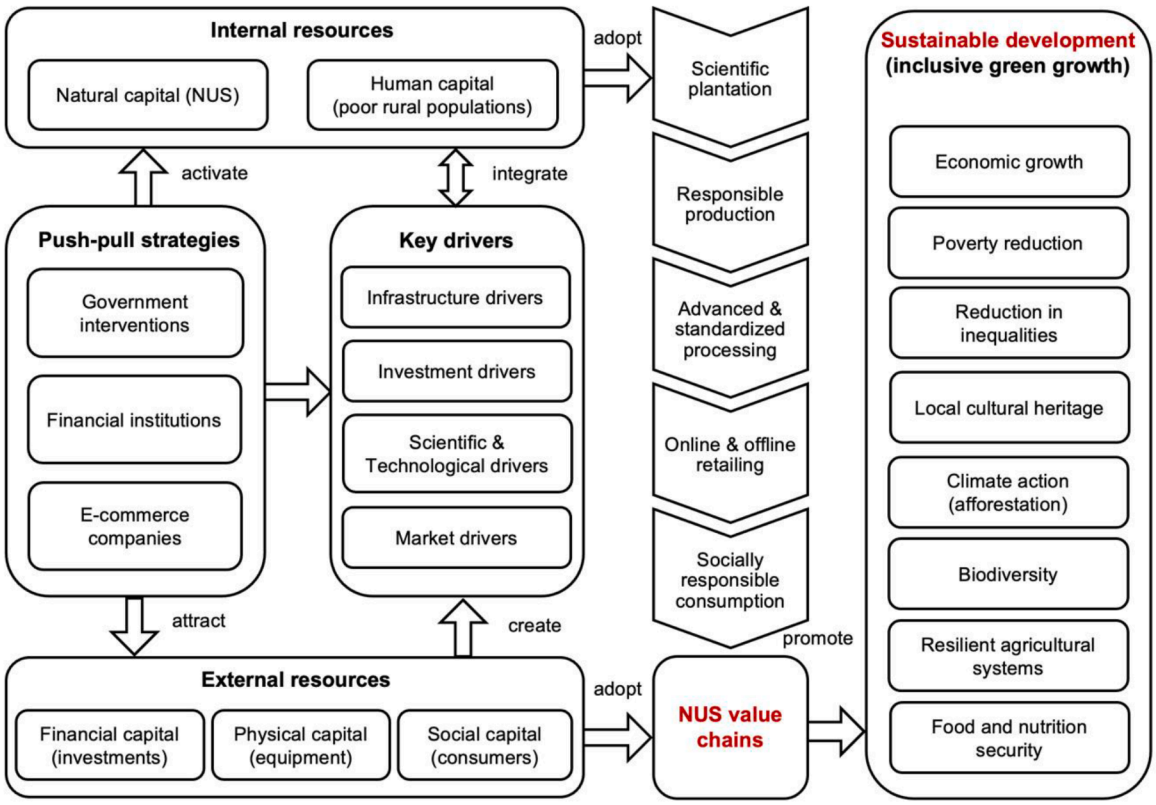

Fig. 3. Conceptual framework of NUS value chain adoption for achieving SDGs.

marginalized regions, countering the challenges of rural out-migration and aging populations discussed by Chen et al. (2014). This also supports the effectiveness of market-based poverty alleviation approach highlighted by Li et al. (2019), demonstrating how integrating poor populations into market systems can actively empower them.

Consistent with Kyaw et al. (2018) and Ogutu et al. (2014), our study shows that ICTs is a critical enabler for providing poor population in rural remote areas with enhanced market access, information, and resources previously out of reach. Specifically, ICTs allow more mindful consumers discussed by Sheth et al. (2010) to know sea buckthorn products and their contributions to afforestation, job creation and poverty reduction, as well as rural economic growth. More interestingly, our study innovatively found that the success of ICT-driven NUS-based industries in remote rural areas might do not require every value chain stakeholder to have ICT skills. The e-CPA interventions mainly targeted the sea buckthorn enterprises and facilitated the adoption of e-commerce of processing enterprises and retailers in the value chain, but still indirectly benefited local poor populations as sea buckthorn pickers and other employees. While many local pickers and brokers were not adept at using the internet, they still experienced income growth as long as they engaged in value chain activities.

Overall, the findings have three implications. First, besides scientific and technological drivers and market drivers, infrastructure drivers and market drivers are two new identified drivers for adopting new NUS value chains. The interaction among different drivers can also interact with each other bringing synergic benefits. Second, the proposed conceptual framework based on the first documented successful case of NUS value chain adoption contributes to filling the literature gap and enabling practitioners systematically evaluate the risks and criteria before establishing the value chain. Third, the findings indicate that in this digital era, ICTs play an increasingly important role in empowering SMEs to develop.

6. Conclusion

This research sheds light on the creation of sea buckthorn value chains in rural remote areas in Gansu Province and identifies four key drivers, namely infrastructure, investment, scientific/technological and market drivers, attracting external financial, physical, and social capital and facilitating utilization of internal natural and human capital. The findings demonstrates that NUS, as valuable natural capital, can be strategically adopted within inclusive green value chains benefiting poor populations and offering a holistic approach to sustainable development. By responsibly planting, producing, processing, marketing and consuming NUS, collaboration among value chain stakeholders and push-pull strategies by inclusive institutions can make the most of the potential of NUS to achieve SDGs without significant trade-offs.

This study has several limitations. First, the selected research sites are three counties in Gansu Province, but the sea buckthorn industry has also been developed in other provinces. More research is expected to explore potential new business models to commoditize NUS. Second, the investigated rural areas have access to road and digital infrastructure to some extent. For some African developing areas who do not have access to electricity, our framework may be not suitable for them to adopt. Third, this study conducted two site visits within one year, and long-term observations would be more appreciated if the objective of NUS utilization is sustainability.

Therefore, future research could explore the following aspects. First, the scalability of the NUS value chain model to other regions with NUS resources and access to road and digital infrastructure is worth researching. Meanwhile, new models for regions without basic infrastructure are also expected. Second, more longitudinal studies can be conducted to track the long-term economic and ecological impacts. Third, more scientific research is required to investigate the potential for technological innovations in NUS value chains. Finally, it is expected to develop more comprehensive frameworks for creating NUS value chains, measuring the multidimensional benefits of NUS to balance

economic, social, and ecological goals.

CRediT authorship contribution statement

Haoxu Zhang: Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Elena Millan:** Writing – review & editing, Supervision. **Kevin Money:** Writing – review & editing, Supervision. **Pei Guo:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Components of sea buckthorn (genus *Hippophae* L., family *Eleagnaceae*)

Attribute	Component	g/kg FW	mg/kg FW	% of total	Nutrition/Function
Moisture (%)		53–86 (berries).			
Total carbohydrates	*Monosaccharides, Polysaccharides*	291 (berries).			Sugars and sugar derivatives influence sensory properties.
Total oil		15–105 (berries).			Palmitoleic acid is beneficial for epithelial tissues including the digestive organs, respiratory, urological, the female genitalia, and the inside of the eye (dry eye syndrome). Sea buckthorn oil can be used in cosmetics emulation to improve hydration and elasticity of the skin, reduce wrinkles and reduce inflammation. It can also relieve skin burns, irritation, sores, and skin changes.
	Palmitic acid			6–11.3 (seed), 15–40 (pulp).	
	Palmitoleic acid (omega-7)			0.8–5 (seed), 15–50 (pulp).	
	Stearic acid			2.6 (seed), 0.55–1.37 (pulp).	
	Oleic acid (omega-9)			15–26 (seed), 10–26.2 (pulp).	
	Linoleic acid (omega-6)			35–40 (seed), 4.4–15 (pulp).	
	Linolenic acid (omega-3)			17.5–35 (seed), 0.4–10 (pulp).	
Crude protein		11–31 (berries).			Berries, leaves, and seeds can be food.
Crude fibre		47.1 (berries).			has strong sorptive properties for heavy metals.
Ash		3–18 (berries).			
Vitamin C		0.25–30 (berries).			For mucosa injuries, maintenance of membrane cell integrity, and as antioxidant.
Vitamin E		0.03–0.21 (berries).			has significant antioxidative effect and offers protection against oxidative stress.
	α-tocopherol		28–176 (berries), 21–168 (pulp), 630–1940 (pulp oil), 42–160 (seeds), 444–1550 (seed oil).		
	β-tocopherol		1.3–1.7 (berries), 1.2–19 (pulp), 10–16 (seeds), 67–164 (seed oil).		
	γ-tocopherol		2.2–15 (berries), 0.6–13 (pulp), 1–3 (pulp oil), 56–95 (seeds), 461–1349 (seed oil).		
	δ-tocopherol		0.2–3.4 (berries),		

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Attribute	Component	g/kg FW	mg/kg FW	% of total	Nutrition/Function
			320–490 (pulp oil), 37–113 (seed oil).		
	α-tocotrienol		0.2–4.5 (berries).		
	β-tocotrienol		0.7–2.3 (berries), 3–11 (seeds), 30–120 (seed oil).		
	γ-tocotrienol		0.3–3.5 (berries), 0.6–8.4 (pulp).		
Vitamin K		1.10–2.30 (berries).			helps wounds to heal
Flavonoids		1.68–10 (berries).			Flavonols may prevent and manage chronic diseases such as diabetes, cardiovascular diseases and/or cancer.
Phytosterols		13–20 (berries).			Phytosterols are good to avoid risks such as heart attack and stroke. The phytosterol content of the diet associates with reduction of cancer incidence including cancers of the colon, breast, and prostate. Sea buckthorn is a better source of β-sitosterol than other popular oils such as sunflower oil or virgin olive oil.
	β-sitosterol	3.0–5.7 (pulp oil), 5.6–10.3 (seeds), 5.9–13.8 (seed oil).			
	Campesterol	0.3 (seeds), 0.3–1.9 (seed oil),			
	Stigmastanol	0.6 (seed oil).			
	Stigmasterol	1.0–1.2 (pulp oil), 1.2 (seed oil).			
	Citrostadienol	0.5 (seed oil),			
	Cycloartenol	1.8 (seeds), 1.9 (seed oil).			
	Δ5-Avenasterol	3.5 (seeds), 3.3 (seed oil).			
	Gramisterol	0.5 (seeds), 0.6 (seed oil).			
Total carotenoids		0.01–0.40 (berries)			Good for eye health.
	Zeaxanthin			1.9–7.8 (berries)	
	Lycopene			1.4–7.8 (berries)	
	β-cryptoxanthin			nd-1.7 (berries)	
	α-carotene			nd-2.5 (berries)	
	β-carotene			4.6–26 (berries)	
	γ-carotene			nd-3.7 (berries)	
	Lutein			nd-2.2 (berries)	

Appendix B. Participant list

ID	Gender	Age	Interview type	Geographical location	Professional status
P1	Male	40–50	Face-to-face	County A	Senior Local Government Officer
P2	Male	40–50	Face-to-face	County A	Officer at the Agriculture and Rural Affairs
P3	Male	40–50	Face-to-face	County A	Officer at the Commerce Affairs
P4	Male	40–50	Face-to-face	County A	Senior Manager of a Sea Buckthorn Processing Company
P5	Male	40–50	Face-to-face	County A	Technical Director of a Sea Buckthorn Processing Company
P6	Male	40–50	Face-to-face	County A	Broker
P7	Male	50–60	Face-to-face	County A	Broker
P8	Male	50–60	Face-to-face	County A	A town's Mayor
P9	Male	40–50	Face-to-face	County A	Berries Picker
P10	Male	50–60	Face-to-face	County A	Berries Picker
P11	Male	60–70	Face-to-face	County A	Berries Picker
P12	Male	20–30	Phone	County A	Consumer of Sea Buckthorn Concentrated Juice
P13	Female	20–30	Phone	County A	Consumer of Sea Buckthorn Concentrated Juice

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ID	Gender	Age	Interview type	Geographical location	Professional status
P14	Male	30–40	Phone	County A	Consumer of Sea Buckthorn Concentrated Juice
P15	Female	30–40	Phone	County A	Consumer of Sea Buckthorn Concentrated Juice
P16	Male	40–50	Face-to-face	County B	Senior Local Government Officer
P17	Male	40–50	Face-to-face	County B	Officer at the Agriculture and Rural Affairs
P18	Male	40–50	Face-to-face	County B	Officer at the Commerce Affairs
P19	Female	30–40	Face-to-face	County B	A town's Mayor
P20	Male	40–50	Face-to-face	County B	Senior Manager of a Sea Buckthorn Processing Company
P21	Male	30–40	Face-to-face	County B	Technical Director of a Sea Buckthorn Processing Company
P22	Female	30–40	Face-to-face	County B	Saleswoman of a Sea Buckthorn Processing Company
P23	Male	20–30	Face-to-face	County B	Express Delivery Packer of a Sea Buckthorn Processing Company
P24	Male	30–40	Face-to-face	County B	Processor of a Sea Buckthorn Processing Company
P25	Male	30–40	Face-to-face	County B	Broker (small)
P26	Male	50–60	Face-to-face	County B	Broker (large)
P27	Male	30–40	Face-to-face	County B	Retailer (A Souvenirs Store)
P28	Male	50–60	Face-to-face	County B	Berries Picker
P29	Male	50–60	Face-to-face	County B	Berries Picker
P30	Male	50–60	Face-to-face	County B	Berries Picker
P31	Female	50–60	Face-to-face	County B	Berries Picker
P32	Male	20–30	Phone	County B	Consumer of Sea Buckthorn Concentrated Juice
P33	Female	20–30	Phone	County B	Consumer of Sea Buckthorn Concentrated Juice
P34	Male	70–80	Phone	County B	Consumer of Sea Buckthorn Concentrated Juice
P35	Female	30–40	Phone	County B	Consumer of Sea Buckthorn Concentrated Juice
P36	Male	40–50	Phone	County B	Consumer of Sea Buckthorn Seed/Pulp Oil
P37	Female	40–50	Phone	County B	Consumer of Sea Buckthorn Seed/Pulp Oil
P38	Male	40–50	Phone	County B	Consumer of Sea Buckthorn Concentrated Juice and Seed/Pulp Oil
P39	Female	40–50	Face-to-face	County B	Restaurant Manager
P40	Female	50–60	Face-to-face	County B	Agritainment / House Farm Manager
P41	Male	40–50	Face-to-face	County C	Senior Local Government Officer
P42	Male	40–50	Face-to-face	County C	Officer at the Agriculture and Rural Affairs
P43	Male	40–50	Face-to-face	County C	Officer at Commerce Affairs
P44	Male	40–50	Face-to-face	County C	Officer at a Sea Buckthorn Research Institute
P45	Male	40–50	Face-to-face	County C	Senior Manager of a Sea Buckthorn Processing Company
P46	Female	30–40	Face-to-face	County C	Saleswoman of a Sea Buckthorn Processing Company
P47	Male	40–50	Face-to-face	County C	Broker (small)
P48	Male	40–50	Face-to-face	County C	Broker (large)
P49	Male	40–50	Face-to-face	County C	Berries Picker
P50	Male	50–60	Face-to-face	County C	Berries Picker
P51	Male	50–60	Face-to-face	County C	Berries Picker
P52	Male	20–30	Phone	County C	Consumer of Sea Buckthorn Concentrated Juice
P53	Female	20–30	Phone	County C	Consumer of Sea Buckthorn Concentrated Juice
P54	Male	30–40	Phone	County C	Consumer of Sea Buckthorn Concentrated Juice
P55	Female	30–40	Phone	County C	Consumer of Sea Buckthorn Concentrated Juice
P56	Male	50–60	Phone	County C	Consumer of Sea Buckthorn Concentrated Juice
P57	Female	50–60	Phone	County C	Consumer of Sea Buckthorn Seed/Pulp Oil
P58	Female	40–50	Face-to-face	County C	Restaurant Manager
P59	Female	50–60	Face-to-face	County C	Agritainment / House Farm Manager

Appendix C. Interview Guide

1. Age: _ 20–30 _ 30–40 _ 40–50 _ 50–60 _ 60–70 _ 70+
2. Gender: _
3. Role (i.e., picker, broker, enterprise, retailer, consumer, government officer): _

Questions to government officers

What is the county's sea buckthorn planting history∝
What are the varieties of sea buckthorn planted in the county?
What are existing planting conditions, such as plantation size, production volume?
Why did the county develop the sea buckthorn industry?
What are factors that influence the yield and quality of sea buckthorn products?
What are incentives and income increasing effect for individual sea buckthorn pickers?
What measures has the local government taken to enhance the influence and sales volume of local sea buckthorn?
What are plans or ideas for developing the local sea buckthorn industry in future?

Questions to pickers and brokers

Why did you choose to enter the sea buckthorn industry? How is the income?

After harvesting sea buckthorn, what are the purchase prices, standards, and quantities?
What benefits/costs have you received while engaging in value chain activities (i.e. picking, trading)?
What challenges have you encountered while engaging in value chain activities?

Questions to sea buckthorn companies

What are the steps involved in the sea buckthorn production process? What kind of sea buckthorn products do you sell?
What are factors that influence the yield and quality of sea buckthorn products?
What is the business model of the company's sea buckthorn products?
How is the sales situation for sea buckthorn products?
What activities do you (or your organization) carry out to add value to the sea buckthorn product?
Have you attempted online promotion and sales? If you have, how has the sales situation been?
What challenges have you encountered while engaging in value chain activities?

Questions to retailers

What kind of sea buckthorn products do you sell?
What are your sales strategies and tactics for selling sea buckthorn products? How has the sales situation been so far?
What challenges have you encountered while engaging in value chain activities?

Questions to consumers

How did you first learn about sea buckthorn juice as a product?
How often do you purchase sea buckthorn juice?
Do you like its taste?
Do you plan to continue buying it?
What factors have influenced your decision to repurchase the product?

Appendix D. Specialty Funds to Huachi, Zhang, and Weiyuan Counties during 2012–2023

Year	Industry Poverty Alleviation Fund	E-commerce Poverty Alleviation Fund	Road Infrastructure Investment	Completed Kilometers	Total Fund (million RMB)
Huachi County					
2012	4.63	0	59.46	72.8	64.09
2013	11.28	0	291.19	232.7	302.47
2014	3.46	0	181.69	169.9	185.15
2015	7.47	0.08	311.34	273.4	318.89
2016	28.03	0.23	181.12	281.5	209.38
2017	24.59	0.47	164.72	180.55	189.78
2018	71.98	0	87.25	72.7	159.23
2019	124.45	0	5.63	15.7	130.08
2020	142.90	0.55	26.60	60	170.05
2021	130.57	0	73.03	101	203.6
2022	151.21	0	106.33	138	257.54
2023	154.37	0	94.75	113.9	249.12
Sum	854.94	1.33	1583.11	1712.15	2439.38
Zhang County					
2012	11.54	0	22.75	65.00	34.29
2013	13.90	0	39.20	78.40	53.10
2014	11.78	0	182.33	451.60	194.11
2015	27.82	10	214.10	423.20	251.92
2016	41.47	67.06	12.49	360.30	121.02
2017	114.31	53	40.48	395.60	207.79
2018	147.90	100.86	44.96	105.38	293.72
2019	185.48	0	111.05	78.11	296.53
2020	184.97	0	85.70	64.19	270.67
2021	134.75	0	83.25	91.74	218
2022	165.04	9	294.75	144.42	468.79
2023	159.01	0	42.20	74	201.21
Sum	1197.95	239.92	1173.26	2331.93	2611.13
Weiyuan County					
2012	15.97	0	14.84	42.40	30.81
2013	36.82	0	62.43	132.90	99.25
2014	99.10	0	71.57	133.85	170.67
2015	121.97	1.09	156.72	285.60	279.78
2016	135.36	0.42	378.52	256.65	514.3
2017	168.74	0.73	177.81	242.90	347.28
2018	608.04	0.11	102.99	148.13	711.14
2019	788.92	1.42	112.39	218.60	902.73
2020	439.66	0.97	172.40	349.91	613.03
2021	347.54	3.00	177.74	322.04	528.28
2022	471.50	0.49	269.11	440.42	741.1

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Year	Industry Poverty Alleviation Fund	E-commerce Poverty Alleviation Fund	Road Infrastructure Investment	Completed Kilometers	Total Fund (million RMB)
2023	449.47	0.44	37.55	101.38	487.46
Sum	3683.08	8.67	1734.06	2674.78	5425.81

Data availability

Data will be made available on request.

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