Deliverable 2.3

Biodiversity in the value chain review

Project Acronym	**BIOVALUE**
Project Title	Fork-to-farm agent-based simulation tool augmenting BIOdiversity in the agri-food VALUE chain
Call	SFS-01-2018-2019-2020: Biodiversity in action: across farmland and the value chain
Type	Report
Dissemination Level	Public
Beneficiaries	Lead: [1]EMÜ, Contributing: [2]NIBIO, [3]AUTH, [4]JLU, [5]MAICH, [6]EGE, [7]CAPNUTRA
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Due date of deliverable	31.12.2022

Disclaimer

Cite this deliverable as: BIOVALUE – D2.3 (2022), Deliverable 2.3 – Biodiversity in the value chain review.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000499

Executive Summary

This study reviews the current information on the crop value chains that support biodiversity and analyses their critical endogenous and exogeneous factors. The underlying assumption of this study is that increasing the diversity of crops by cultivating neglected and underutilized crop varieties and landraces has a positive effect on biodiversity. The study uses a systematic literature review approach. A total of 1193 individual publications were found as a result of the queries done on 18 January 2022. After applying several exclusion criteria, the final criteria for inclusion were that publications examined a particular crop or group of crops in particular country or a region, and were not itself reviews. 54 papers met these criteria. After the thematic coding and internal reviews, the following value chain segments were analysed: inputs, farmers, processing industry, distribution, and consumers. Additionally, institutions and policy emerged as important topic. Of the reviewed papers, 37% studied cereals and legumes, 28% studied fruits and vegetables, 12% focused on coffee, cocoa or tea, 9% studied potato varieties, and 9% studied crops grown by trees either in forests or plantations.

Seeds are the most critical input for farmers. Constraints for accessing quality seeds, and organization of supply of seeds are the two most important challenges to tackle. Often, underutilized crops and landraces are cultivated in marginal or fallow lands by small-scale farmers. This makes it difficult to achieve economies of scale via mechanization and other techniques. In case of some crops, postharvest handling and storage facilities are important to secure quality of the products, and thereby lack of resources and/or access to capital might be a significant barrier. Many authors have established that underutilized or neglected crops, and landrace varieties are cultivated in sustainable management systems, which benefit from the feedbacks within the systems. However, sometimes low input systems are not coping well with diseases and pests.

One of the main benefits for farmers and small-scale processors from participating in short supply chains lies in earning higher premiums by cutting out one or more segments of the value chain. The marketing activities of small-scale farmers need to be coordinated to achieve sufficient product volumes for processing industry or retailers. Coordination of market activities with smallholders can be challenging because sometimes they operate according to different logic than value chains. Therefore, middlemen, collector agents or wholesalers have an important role in securing demand for the products through their networking and business skills.

In general, cultivating niche crops may provide an opportunity for earning price premium. More diversified crop production inevitably results with more varied quality of the products and less products with identical quality parameters. However, for the processing industry the raw material needs to correspond to certain quality, technical and sanitary standards. At the same time, smallholders might have difficulties in fully understanding the importance of quality requirements. For retailers, one of the main motivations to work with such products is distinguishing themselves from competition. Retailers may buy products from distributors or directly from farmers but often the low and unstable supply and quality are problems.

The demand for products based on landraces, underutilized and neglected crops might be low for several reasons – these products may be used as accessory foods rather than staples, consumers may have lost habit of consumption of these products and might consider them old-fashioned or not tasty, they might be unaware of the nutritional and/or medicinal qualities of the products. Also, consumers may be unaware of and therefore not value the agroecology of certain products, the products may be

available only seasonally. It is important to create trust among consumers towards the products, especially when it comes to launching new products on the market. The quality of a products needs to be defined and also guaranteed. However, due to increasing number and complexity of certificates and labels and competition between these, it is becoming questionable to what extent these inform consumers, affect their willingness to purchase and pay, and to what extent these schemes benefit producers. Through social innovation, it is also possible to establish informal systems to assure product quality for consumers. Therefore, local short supply chains could be de facto transparent also without formal quality assurance schemes, while global chains need to develop and use formalized certification and labelling schemes.

The role of institutions and policy in this context is to create an enabling environment for development of value chains that support biodiversity. No single actor or value chain segment can preserve certain variety or develop value chain for its products. Therefore, value chain governance is of importance. Successful development of value chains needs long-term commitment, and lack of continuity of public policies due to government changes poses a risk thereof. It has been suggested that value chains itself have a limited effect on biodiversity conservation, thereby in addition to market-oriented solutions, complementary conservation strategies should be planned and executed.

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Abbreviations and Acronyms

BioValue	BioValue project – Fork-to-farm agent-based simulation tool augmenting BIOdiversity in the agri-food VALUE chain
HoReCa	Hotels, restaurants and catering
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses

1. Introduction

The situation of farm-level biodiversity in agricultural systems is influenced by the conditions in the relevant food, feedstuff, fuel and fibre markets. However, there is an ample evidence about the market failures leading to biodiversity loss due to the externalities and the public-good nature of biodiversity conservation. In addition to market signals, farmers' choices are affected by a number of factors, including social, political and cultural conditions in which they operate. Ultimately, these factors also affect biodiversity, and in turn, loss of biodiversity is damaging the resilience of food systems and increasing risk of food insecurity in long term. Hence, more knowledge is needed on how value chains can support production and consumption of more diverse crops and thereby positively contribute to biodiversity.

Therefore, the task 2.3 of the BioValue project aims to provide the most current information on biodiversity in the crop value chains and analyse its critical endogenous and exogeneous factors that display increasing effect on the biodiversity.

This study reviews the roles and interrelations of the following segments of the crops' value chains – input suppliers, farmers, processing industry, distribution, and consumers – as well as institutions and policy in this context. The study applies the methodology of systematic literature review.

2. Methodology

In order to provide the current information on how the crop value chains can support biodiversity, a systematic literature review was done. Due to the exponential growth in the number of academic publications, systematic literature reviews are an increasingly common method to summarize existing knowledge of a research problem or a research field.

In this study, PRISMA[1] guidelines (Liberati et al., 2009) were followed to gain overview about the relevant literature. Literature was collected from two databases: 1) Scopus and 2) Web of Science. Both databases include peer-reviewed academic publications. The query was designed broadly, so that the responses had to include at least two concepts: biodiversity and value chain. These were defined via several related words. Search term biodiversity included words biodiversity, habitat, soil quality, water quality. Search term value chain included words value chain, supply chain, agri-food.

Specifically, the search query in Scopus included the title, abstract and keywords from which following terms were searched: "TITLE-ABS-KEY(biodiversity OR habitat OR "soil quality" OR "water quality") AND TITLE-ABS-KEY("value chain" OR "supply chain" OR "agri-food")". In Web of Science,

[1] Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

the search was done from same attributes of publications using query: "TS=(biodiversity OR habitat OR "soil quality" OR "water quality") AND TS=("value chain" OR "supply chain" OR "agri-food")".

The queries were done on 18 January 2022 and thus included all publications published prior to that date. A total of 1656 publications was found as a result of the queries. The results of the queries were exported as ".bib" files and further processed using R packages "synthesisr" to identify and remove duplicates that were due to an overlap of publications in Scopus and Web of Science databases. After removal of duplicates, 1193 individual publications remained.

Initial analysis of retrieved publications by using tools of term frequency, word cloud, topic modelling, and term correlations indicated that some repeatedly occurring topics that were not relevant for this study. In order to select, which of the publications to exclude, the occurrence of the following stemmed words was counted: water, forest, biomass, fish, livestock, animal production, anim, dairy, milk, meat, biofuel, medicin, oil palm, palm oil, gm, biotechnolog, tourism, cosmet, cobalt, robot, sensor network, orbit, indium, LNG. These words were used to exclude publications from the review due to not being relevant.

The full texts of each remaining publication were read by at least two researchers. Criteria for inclusion at this stage were that publications examined a particular crop or group of crops in particular country or a region, and were not itself reviews of previous research. 54 papers met these criteria, and each of these papers were further examined by at least two researchers to extract all relevant information regarding how biodiversity is supported by the crop value chains.

The analysis did not focus on the effects of diversifying crop value chains on biodiversity. Most of the papers did not include any explicit impact assessment on biodiversity. Rather, the underlying assumption of this study, and also of the reviewed papers, was that increasing the diversity of crops by cultivating neglected and/or underutilized crop varieties and/or landraces itself would have positive effect on biodiversity.

The initial data collection from the 54 selected papers utilized a supply chain framework that included the following segments: inputs, farmers, logistics and infrastructure, processing industry, distribution, HoReCa, and consumers. The researchers extracted from the 54 papers the relevant sentences related to the role of each segment in supporting cultivation of more diverse crops and varieties. These excerpts were further thematically coded. After the initial coding, two internal reviews were done by four researchers to consolidate and rearrange the occurred themes. The interim results of the analysis were discussed in two BioValue project's general meetings. These discussions gave further reflections on the occurred themes and their interrelations. After the thematic coding and internal reviews, initial logistics and infrastructure segment of the value chain was merged with the farmers' segment, and similarly, HoReCa segment was merged with distribution segment. Additionally, the theme 'institutions and policy' was created, which is not part of the value chain, but has significant effect on the economic, political and cultural environments where the value chains function.

For each paper in the full dataset of 54 papers, a record was done to indicate, which segments of the value chain, and emerging subthemes under each segment the paper addresses. This dataset was the basis for creating statistical overview of the reviewed literature.

3. Results and discussion

3.1 Statistical overview of the literature

Figure 1 provides a general overview of the temporal distribution of reviewed papers in the period 2004–2021. While in the sub-period 2004–2014, one or two papers were published each year, in recent years the topic of biodiversity in crop value chains has gained more attention. However, based on this dataset, it is not possible to determine to which extent this is due to increasing relevance of the topic, and to which extent this trend is affected by the general exponential increase of peer-reviewed academic papers.

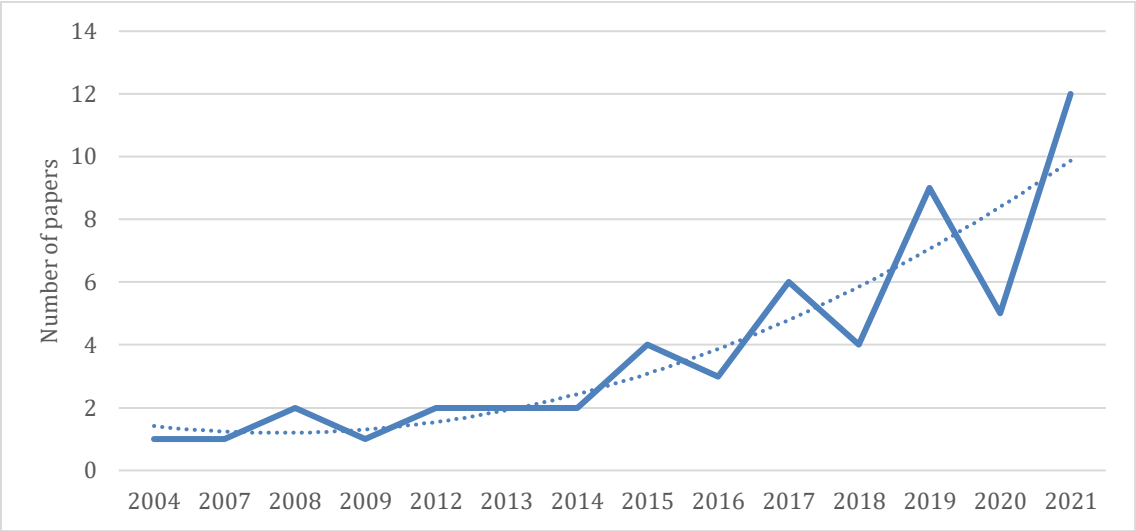

Figure 1: Number of publications by year

Farmers are the value chain segment, that has been studied the most (Figure 2). This segment was discussed in 35 papers (65%). Also, inputs, consumers, and institutions and policy issues have been frequently analysed in the literature, while processing and distribution aspects have received less attention (in 18 and 20 papers, respectively). On the one hand, considering that the number of processing and distribution (wholesalers and retailers) companies is relatively small compared to number of famers and consumers, such distribution is in accordance with expectations. On the other hand, given that the value chains function as a whole and all segments or at least processes related to these segments, should be considered, this suggests that processing industry and distribution segments need more attention in relation to biodiversity in crop value chains.

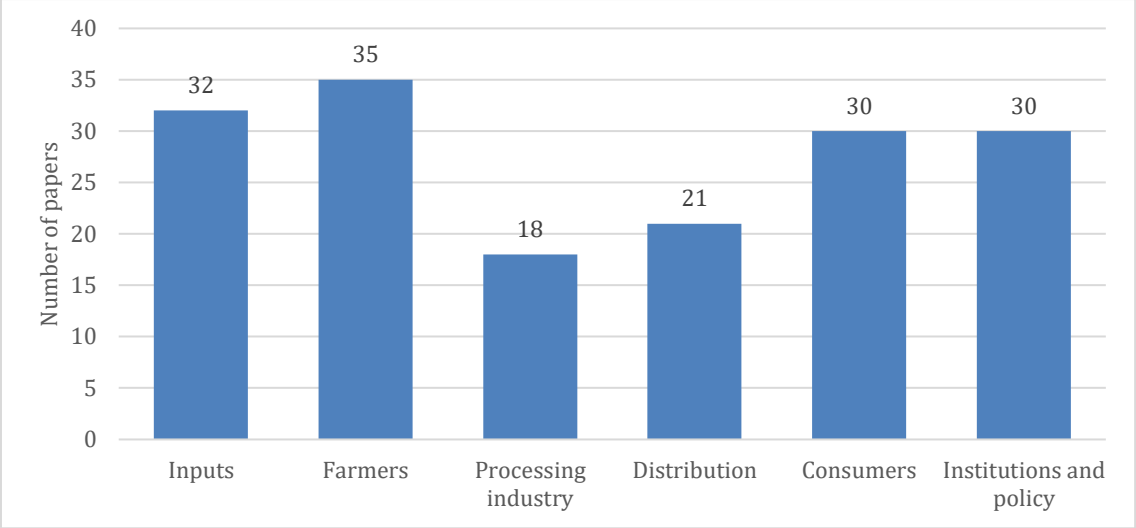

Figure 2: Coverage of value chain segments

Comparison of coverage of value chain segments in sub-periods between 2004 and 2021 shows that about 40% of papers cover the first segments of the value chain, i.e. inputs and farmers (Figure 3). Only in the sub-period 2009–2013 these segments received relatively less attention, and the focus of papers was more on consumers, institutions and policy. While the total number of the papers has increased in recent years, also the number of papers covering the processing industry and distribution segments has increased.

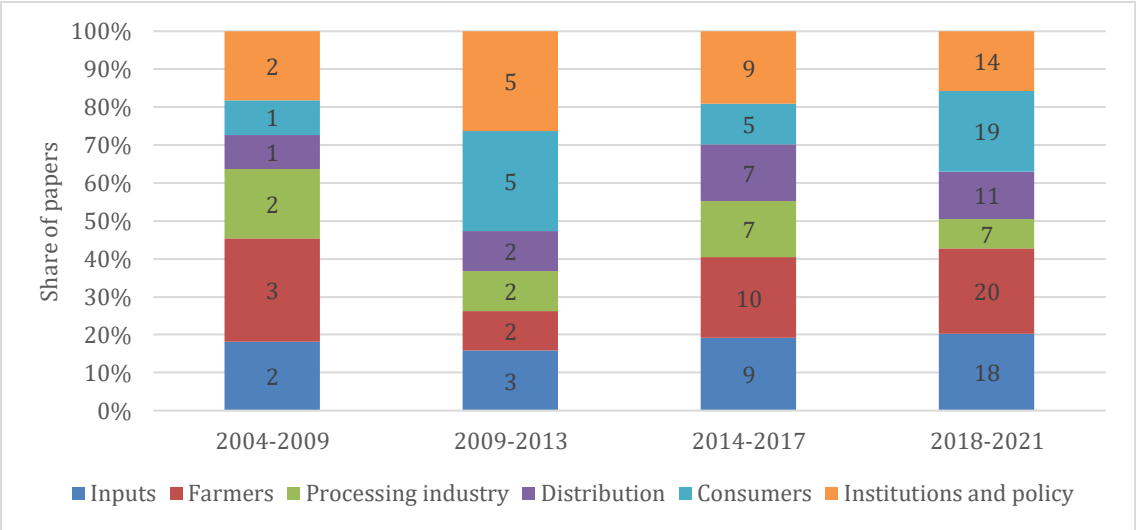

Figure 3: Coverage of value chain segments by periods

In terms of coverage of groups of crops, 37% of papers studied cereals and legumes, 28% of papers studied fruits and vegetables, 12% of papers focused on coffee, cocoa, or tea, 9% of papers studies potato varieties, and 9% of papers studied crops grown by trees either in forests or plantations. Therefore, the main groups or types of crops are covered relatively evenly in the reviewed literature.

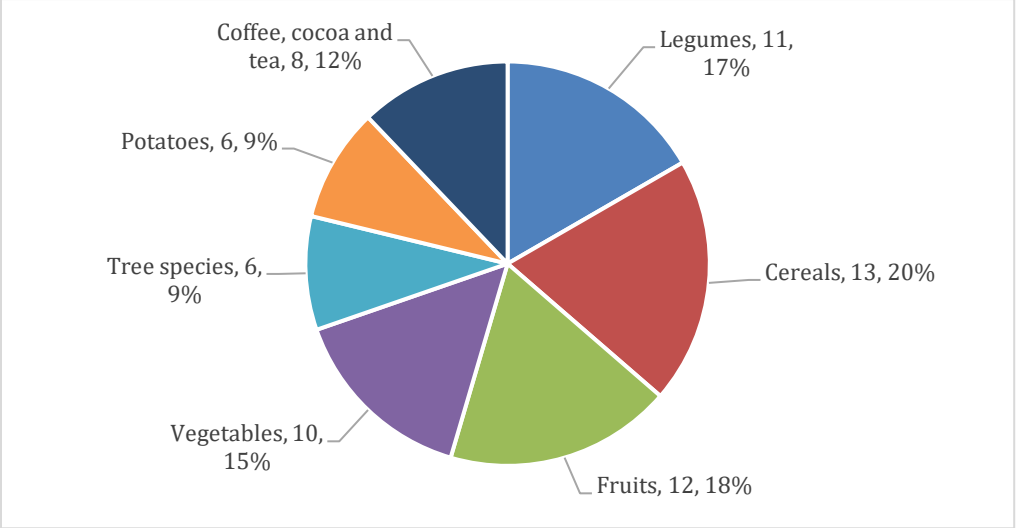

Figure 4: Coverage by groups of crops

In terms of the world regions where the reviewed studies were conducted, 30% of the papers focused on Asia, 29% on Europe, and 27% on Americas (Figure 5). Only 6% and 2% of the papers focused on Africa and Oceania, respectively. If we compare what kind of crops and their value chains have been studied in different regions of the world, then some peculiarities occur (Figure 6). In Americas, relatively more studies, compared to other regions of the world, focused on fruits (26%) and potatoes (21%). In Africa, more focus has been on legumes (33%) and coffee, cocoa and tea (33%). In Asia, the focus has been mainly on coffee, cocoa and tea (32%) and cereals (26%). In Europe, compared to other regions, vegetables (32%) have received more attention. In Oceania, the number of papers is too small to draw any conclusions.

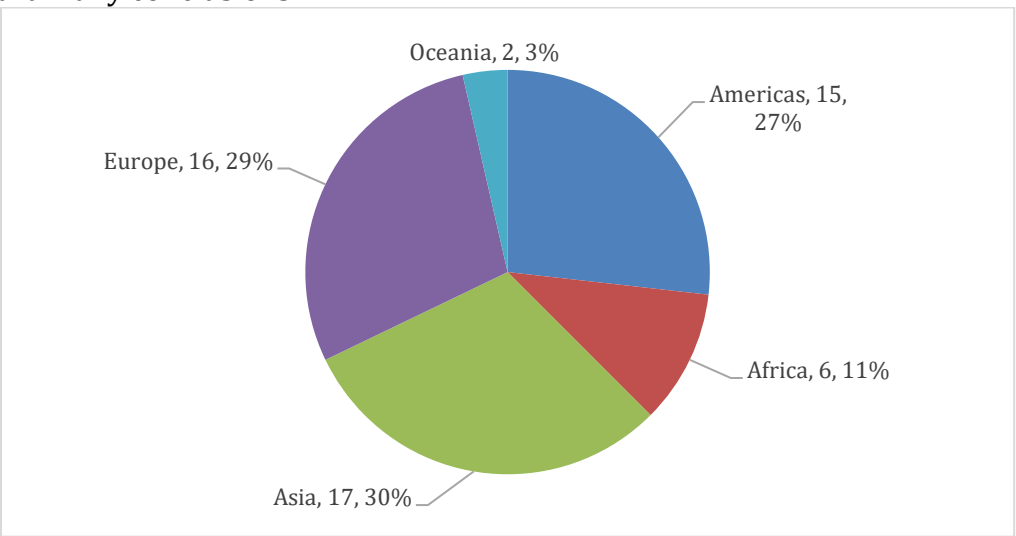

Figure 5: Coverage by world regions

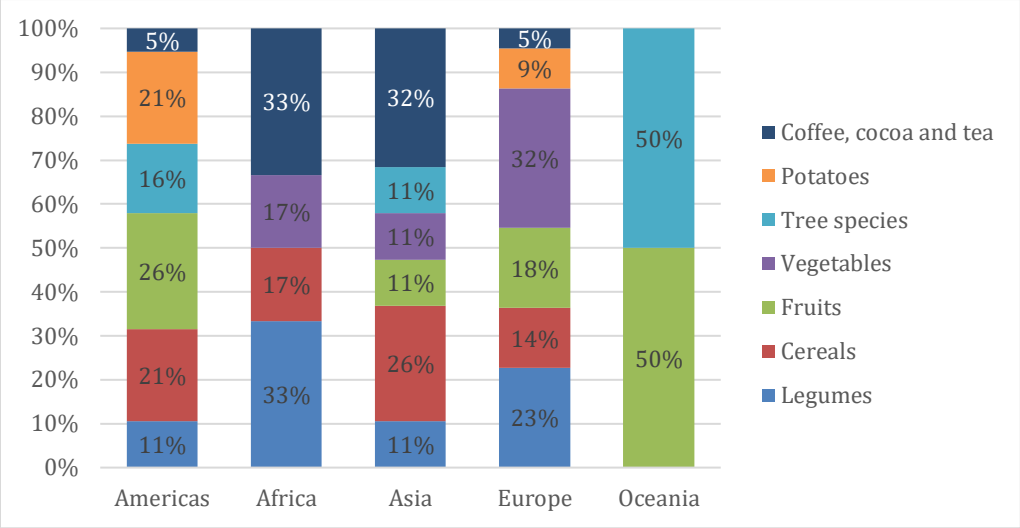

Figure 6: Coverage by groups of crops and world regions

As mentioned above, the following value chain segments were analysed: inputs, farmers, processing industry, distribution, and consumers. Additionally, institutions and policy emerged as important topic. Thematic coding of excerpts resulted with several repeatedly occurring themes in each value chain segment and also under institutions and policy theme. Table 1 presents and overview of the themes.

Table 1: Value chain segments and themes

Inputs	Farmers	Processing industry	Distribution	Consumers	Institutions and policy
• Seeds • Environmental conditions • Land • Capital • Fertilizers and plant protection • Labour	• Production methods and systems • Productivity, income and prices • Product quality and quantity • Marketing options • Knowledge	• Technology • Quality, quantity and seasonality of primary products • Differentiating from competition • Multi-stakeholder partnerships	• Coordination of supply • Short supply chains • Large-scale retailers • HoReCa • Markets • Quality, quantity and seasonality of primary products	• Quality, certificates, labelling and traceability • Consumer awareness and preferences • Cultural traditions and familiarity to products	• Supporting organisations • Breeding programs • Governance • Food security • Income and investment support • Research and development • Farmers' collaboration and cooperation • Strategic planning

	• Community and, cultural identity • Post-harvest handling, storage and logistics • Collaboration between farms			• Marketing strategies • Cookability	• Trade policy • Knowledge transfer • Market support measures • Protection of genetic diversity • Regulations

Note: Themes are presented in descending order, depending on the number of papers that cover these

Further, correlation analysis was done to explore, which value chain segments, topics and themes have been studied concurrently. The rationale for the correlation analysis stemmed from the assumption that in order to understand functioning of value chains, all relevant segments and their interrelationships should be considered. From Table 2 it appears that papers that studied the inputs segment, often also studied the distribution segment of the value chains, and also institutions and policy issues. Farmers have been studied more frequently together with distribution issues. The same applies to the processing industry segment. Distribution segment has statistically significant correlations with all the other segments of the value chain, and also with institutions and policy issues. Consumer issues have mainly been studied together with distribution, and institutions and policy issues.

Table 2: Correlations between value chain segments, and institutions and policy topic

	Consumers	Distribution	Farmers	Inputs	Institutions and policy
Distribution	0.41**				
Farmers	0.11	0.36**			
Inputs	0.17	0.48***	0.02		
Institutions and policy	0.32*	0.33*	0.11	0.32*	
Processing industry	0.00	0.32*	0.21	-0.08	0.16

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

The following tables 3–8 present correlations between themes under each of the crop value chain segments, and institutions and policy topic. This gives further and more in-depth insights as to which themes are studied in connections to which value chain segments. Also, the tables give information on how many papers have discussed the specific themes. From Table 3, it appears that in the inputs' segment of the value chain there are three themes, which are statistically significantly correlated with other segments of the value chain. Environmental conditions and capital issues are often discussed in relation to distribution segment; and fertilizers and plant protection issues are often analysed jointly with institutions and policy matters.

Table 3: Correlations between themes under the inputs' segment, other value chain segments, institutions and policy

Themes under Inputs	Number of papers	Correlation with other value chain segments and institutions				
		Farmers	Processing industry	Distribution	Consumers	Institutions and policy
Seeds	19	-0.04	-0.18	0.27	0.25	0.18
Environmental conditions	8	0.11	0.04	0.31*	0.27	0.06
Land	7	0.09	-0.04	0.26	0.12	0.23
Capital	6	0.06	0.12	0.32*	0.20	0.20
Fertilizers and plant protection	5	0.03	0.05	0.01	0.03	0.29*

Themes under Inputs	Number of papers	Correlation with other value chain segments and institutions				
		Farmers	Processing industry	Distribution	Consumers	Institutions and policy
Labour	2	0.11	0.07	0.25	0.18	0.18

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

Table 4 presents coefficients of correlation between themes under the farmers' segment of the crop value chain, and other value chain segments, institutions and policy. It appears that inputs have frequently been analysed together with marketing options of farmers and their knowledge. Processing industry has most significant connections with the productivity, income and prices themes, as well as product quality and quantity themes. Distribution segment has significant correlations with almost all themes, except knowledge of farmers and their collaboration. Similarly, to processing industry segment, distribution segment has the strongest correlation with product quality and quantity theme. Interestingly, consumers' segment has no significant correlations with any of the themes under the farmers' segment. Institutions and policy issues have been mainly analysed in connection to productivity, income and prices, and product quantity and quality issues of the farmers' segment.

Table 4: Correlation between themes under the farmers' segment, other value chain segments, institutions and policy

Themes under Farmers	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Processing industry	Distribution	Consumers	Institutions and policy
Production methods and systems	22	0.21	0.05	0.34*	0.21	-0.09
Productivity, income and prices	20	0.15	0.27*	0.41**	0.07	0.38**
Product quality and quantity	17	0.12	0.54***	0.52***	0.12	0.29*
Marketing options	15	0.31*	0.18	0.44***	0.22	0.22
Knowledge	14	0.33*	0.19	0.20	0.10	0.10
Community and cultural identity	10	0.14	0.17	0.40**	0.14	0.14
Post-harvest handling, storage and logistics	10	0.14	0.07	0.40**	0.23	0.14
Collaboration between farms	9	0.10	0.21	0.15	-0.10	0.20

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

The number of themes that are considered in the processing industry's segment is smaller than in other segments (Table 5). The only statistically significance correlation was found between quality, quantity and seasonality of primary products, which is frequently discussed together with distribution issues. All other correlation coefficients were not statistically significant.

Table 5: Correlation between themes under the processing industry's segment, other value chain segments, institutions and policy

Themes under Processing industry	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Farmers	Distribution	Consumers	Institutions and policy
Technology	11	-0.18	0.16	0.15	-0.09	0.07
Quality, quantity and seasonality of primary products	8	0.17	0.25	0.48***	0.17	0.17
Differentiating from competition	6	-0.16	0.06	0.08	-0.04	-0.04
Multi-stakeholder partnerships	3	0.05	0.14	0.14	-0.11	0.05

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

Table 6 presents the coefficients of correlation between themes under the distribution segment of the crop value chain, and other segments, institutions and policy. Coordination of supply has been frequently analysed together with inputs and farmers segments. Short supply chains have been analysed together with the consumer issues, and HoReCa together with processing industry issues. The distribution segment also has a theme related to quality, quantity and seasonality of primary products, which is often analysed together with processing industry issues. Therefore, the stability of quantity and quality of the products is one of the key themes that is related to both, processing industry and distribution segments.

Table 6: Correlation between themes under the distribution segment, other value chain segments, institutions and policy

Themes under Distribution	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Farmers	Processing industry	Consumers	Institutions and policy
Coordination of supply	10	0.33*	0.27*	0.17	0.14	0.23
Short supply chains	9	0.20	0.14	0.21	0.30*	0.10
Large-scale retailers	6	0.20	0.20	0.25	0.08	0.20
HoReCa	5	0.16	0.18	0.32*	0.16	0.16
Markets	5	0.16	0.18	0.05	0.16	0.16
Quality, quantity and seasonality of primary products	4	0.17	0.25	0.55***	0.17	0.17

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

In the consumers' segment of the crop value chain, the theme related to quality, certificates, labelling and traceability has often been discussed together with distribution segment, and institutions and policy (Table 7). Also, marketing strategies for reaching consumers have been analysed together with the distribution segment of the crop value chains.

Table 7: Correlation between themes under the consumers' segment, other value chain segments, institutions and policy

Themes under Consumers	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Farmers	Processing industry	Distribution	Institutions and policy
Quality, certificates, labelling and traceability	15	0.06	0.16	0.26	0.35**	0.31*
Consumer awareness and preferences	14	-0.07	0.04	-0.06	0.13	0.02
Cultural traditions and familiarity to products	14	0.02	0.12	0.03	0.20	-0.06

Themes under Consumers	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Farmers	Processing industry	Distribution	Institutions and policy
Marketing strategies	4	0.11	0.16	-0.05	0.35**	0.11
Cookability	3	0.05	-0.24	-0.17	-0.03	0.22

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

There are many themes related to institutions and policy, but of these are not significantly correlated to specific segments of crop value chains (Table 8). The role of supporting organizations has frequently been analysed together with processing industry. Research and development issues have been mainly studied in the context of inputs' segment, and protection of genetic diversity is statistically significantly correlated with distribution supply chain.

Table 8: Correlation between themes under the policy and institutions topic and value chain segments

Themes under Institutions and policy	Number of papers	Correlation with other value chain segments and institutions				
		Inputs	Farmers	Processing industry	Distribution	Consumers
Supporting organisations	7	0.12	0.22	0.31 *	0.26	0.01
Breeding programs	6	0.20	0.06	-0.25	0.20	0.20
Governance	6	0.08	0.06	0.25	0.20	-0.04
Food security	5	0.16	0.03	0.05	0.14	0.16
Income and investment support	5	0.16	0.18	-0.09	0.14	0.03
Research and development	5	0.29*	-0.12	0.05	0.14	0.16
Farmers' collaboration and cooperation	4	0.11	0.16	0.10	0.21	0.11
Strategic planning	4	0.11	-0.01	0.10	0.21	0.11
Trade policy	4	-0.03	-0.01	-0.20	-0.08	0.11
Knowledge transfer	3	0.22	-0.05	0.17	0.14	0.22
Market support measures	3	0.05	0.14	0.00	0.14	0.22
Protection of genetic diversity	3	0.22	0.14	0.00	0.30*	0.22
Regulations	3	0.05	-0.05	0.00	0.14	0.05

Source: own calculations
Note: Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

The results of correlation analysis do not necessarily imply causality between analysis of the themes and value chain segments. These results here are also dependent on the identification of themes by the researchers, and therefore may be affected by a certain degree of subjectivity. However, if one considers the proportion of statistically significant correlations between the themes under a specific value chain segment, and other segments of crop value chains, institutions and policy, then it appears that in case of farmers, 30% of correlation coefficients were statistically significant (Table 4), and in case of distribution, 17% of correlation coefficients were significant (Table 6). Therefore, the interrelations between these two value chain segments and other segments, institutions and policy are better established in the existing literature. On the other hand, in cases of both, processing industry, and institutions and policy, just 5% of the correlation coefficients were statistically significant. This suggests that the roles of processing industry and institutions and policy, and their interconnections with other crop value chain segments have been studies less in the existing literature, and therefore these issues might need more attention in future studies of biodiversity in crop value chains.

3.2 Biodiversity in the crop value chains

Next, a qualitative analysis of the emerged themes under each of the crop value chain segments is presented. The qualitative analysis focuses on bringing out the roles of crop value chain segments, institutions and policy, and their interrelationships with other segments.

3.2.1 Inputs

Seeds

Seeds are the most obvious and also most critical input for farmers, when one considers cultivation of crops. The reviewed literature identified two main issues related to seeds: 1) constraints for accessing quality seeds; 2) organization of supply of seeds.

Constraints for accessing quality seeds

In general, the seed business has a seasonal nature and input (seed) suppliers tend to specialize on mainstream varieties, the seeds of which can be traded in large quantities. Therefore, mainstream (seed) suppliers are often not interested in supplying seeds (of underutilized and neglected crops, and landraces) in niche markets with limited market volumes (Teshome and Duerr 2018; Mbosso et al 2020). Sometimes the seeds are provided by small-scale seed companies (Elia and Santamaria 2013) or local organizations but while they may be cheap and of good quality, there could be problems with their availability on right time (Teshome and Duerr 2018; Rani et al 2018). Sometimes farmers themselves maintain landraces but they have difficulties with quality seed production, maintenance, and storage (Bisht 2021). Better quality and improved seeds secure higher yields for farmers but e.g. hybrid seed may be several times costlier than local landrace seed (Tawk et al 2019; Maretta et al 2021; Keleman et al 2013), and there might be difficulties in accessing these (Mbosso et al 2020; Teshome and Duerr 2018). However, improving the varieties is essential in long term to improve their viability and adaptability to various stresses that arise from climate change (Maretta et al 2021; Kliem and Sievers-Glotzbach 2021; Wall et al 2019).

Organization of supply of seeds

The market channels for seeds in general can be divided to a formal market with commercial or state-led suppliers and an informal market defined by non-profit seed exchange (Pedersen 2020). In formal markets, sometimes national or regional organizations are responsible for supplying the seeds (Sacchi et al 2019; Buchwaldt and Richards 2004; Tawk et al 2019). In some cases, such organizations have a mandate to acquire, maintain, and characterize plant germplasm and microorganisms for preserving biodiversity and supporting development of economically important crops (Buchwaldt and Richards 2004). In traditional subsistence farming communities, farmers have limited access to formal seed systems. This is why the small-holder, subsistence-oriented farmer households rely mainly on community-level informal seed systems for their native crops (Bisht 2021; Elia and Santamaria 2013; Lanka et al 2017; Velázquez-Salazar et al 2021). On the other hand, local seed movements could also create risks for seed borne pathogen spread (Onofre et al 2021). There are also organizations that initiate and help to maintain breeding programs (Maretta et al 2021) and encourage farmers to multiply their own seeds, promote seed exchanges, and foster the establishment of an independent seed sector (Kliem and Sievers-Glotzbach 2021; Sacchi et al 2019). Formal registration of varieties may allow farmers and their groups to develop a new income stream from producing and selling seeds (Li et al 2014).

Environmental conditions

Harsh environmental conditions (Keleman and Hellin 2009), climate change (Liu et al 2015), frost damage (Rani et al 2018), lack of water or too much rain during the harvest period (Rani et al 2018; Mbosso et al 2020; Velmourougane and Bhat 2017; Elia and Santamaria 2013), plant diseases and pests (Rani et al 2018, Teshome and Duerr 2018) are severely straining all agricultural systems, including the systems that cultivate underutilized crops. Better resistance to harsh environmental parameters is in some cases a factor that makes cultivation of underutilized crops and landraces attractive to farms that are faced with environmental degradation (Lanka et al 2017; Keleman and Hellin 2009). However, this also supports the argument that landraces and underutilized crop varieties need to be continuously improved to be more resistant to biotic stresses (Rani et al 2018). In the conditions where water is a limiting production factor, there is a need for irrigation systems, which raises the importance of access to financing (Velmourougane and Bhat 2017).

Land

Often, underutilized crops and landraces are cultivated in marginal or fallow lands (Lanka et al 2017; Vanlauwe et al 2019) by farmers that are operating at relatively small scale (Lanka et al 2017; Keleman et al 2013; Jayasekhar and Hughers 2018). Sometimes, vegetables could be cultivated even in home gardens (Teshome and Duerr 2018). Small scale and fragmented production make it difficult to achieve economies of scale via mechanization and other techniques (Keleman et al 2013). Also, the availability of land affects farmers' decision in two ways: 1) lacking security over long-term land use rights in case of tenants leads more likely to monoculture and less likely to diversified production (Tawk et al 2019); 2) small-scale farmers that can use more land are more likely to diversify their crop portfolios (Tobin et al 2016).

Capital

The importance of access to capital has been raised by many authors. In case of some crops (e.g. vegetables), postharvest handling and storage facilities are important to secure quality of the products, and thereby lack of resources and/or access to capital to invest in such projects might serve as a significant barrier (Tobin and Glenna 2019; Teshome and Duerr 2018; Mbosso et al 2020). Similarly, poor access to credit might hinder use of improved technology and appropriate inputs (Teshome and Duerr 2018; Keleman et al 2013, Velmourougane and Bhat 2017). It has been found that that better access to credit increases farmers' willingness to take financial risks (Keleman et al 2013), a factor that is important in diversifying one's crop portfolio with less known crops. It has been even discussed that since high value markets require more investments and assets, such markets might not be appropriate for lower-income farms (Devaux and Ordinola 2019).

Fertilizers and plant protection

Fertilizers and plant protection chemicals are not specific to underutilized crops, and their accessibility is varying in different regions and countries. However, in some cases, there are cooperatives or local agricultural offices that supply fertilizers to farmers, and plant protection chemicals might not be accessible for farmers (Teshome and Duerr 2018). In some cases, use of agrochemical plant protection agents is more common among farmers than use of organic fertilizers (Tawk et al 2019), indicating the relevance of development of circular production systems to reduce dependence on fossil-based production inputs (Iocola et al 2021). In some regions, earlier indiscriminate use of pesticides has caused resistance development in insect pets, and creating additional challenges for plant protection (Velmourougane and Bhat 2017). Also, plant disease risks may threat crop yields (Onofre et al 2021). Therefore, it is important to increase farmers knowledge on correct practices of use of plant protection chemicals, and also to establish appropriate inspection system for spraying materials, equipment and practices (Fang and Zhu 2014).

Labour

Small-scale farming is often dependent on family labour. Therefore, availability of labour also affects their decisions (Keleman et al 2013). While it has been indicated that small-scale farmers may be more willing to cultivate underutilized crops, labour constraints may restrict diversification of their crop portfolios (Teshome and Duerr 2018), and lead them towards mechanization of production (Keleman et al 2013). At the same time, if household labour is available, farmers are able to use traditional production and harvesting techniques, which may give them an advantage to produce and sell wider range of products (and by-products) (Keleman et al 2013).

3.2.2 Farmers

Production methods and systems

Farmers are the segment of crop value chains whose decisions directly affect biodiversity. They are inherently related to some of the inputs, e.g. labour, land and environmental conditions, and some of farmers' characteristics could be considered as an input, e.g. knowledge. From the family labour perspective, it has been found that women could be involved in processing activities due to difficult nature of some of production activities (Mbosso et al 2020). While often small-scale farms use low- or medium-technology systems, lack of labour availability pushes them for mechanisation of some of the field operations (Keleman 2013). It has also been found that land plots that do not succeed with other crops might be used for crops that are not demanding for their inputs (Mbosso et al 2020; Padulosi et al 2015; Amaya et al 2020). Many authors have established that underutilized or neglected crops, and landrace varieties are cultivated in sustainable management systems, which benefit from the feedbacks within the systems (Winans et al 2021; Galli et al 2015; Velázquez-Salazar et al 2021; Garrett and Rausch 2015). Such examples often include diverse and integrated production of different crops and trees (Teshome and Duerr 2018; Veloz 2020; Neilson and Pritchard 2007). Integrated, agroecological and organic production systems are also a way of low input farming, either by choice or due to lack of access to inputs like fertilizers, crop protection chemicals, and irrigation (Teshome and Duerr 2018; Lanka et al 2017; Iocola et al 2018; Liu et al 2015; Padulosi et al 2015). In such conditions, circularity within agricultural systems helps to obtain soil nutrients and replace fertilizers in the form of animal manure, crop residues or vermicomposting (Lanka et al 2017; Tawk et al 2019; Velmourougane and Bhat 2017; Gaitan-Cremaschi et al 2017). Sometimes, low input systems are not coping well with diseases and pests that further hamper the productivity (Teshome and Duerr 2018). In cases were farmers have contracts with processing industry or retailers, they tend to select better land plots and use more synthetic inputs to secure correspondence with the quality requirements (Tobin et al 2016). Also, it has been found that households that participate in organized value chains, grow more varieties than non-participating households (Tobin et al 2016), suggesting the relevance of organized value chains in securing bigger crop diversity. Growth of the production volume may also necessitate changes in production methods, e.g. by upgrading cultivation technology, using superior seeds, and expanding land use (Maretta et al 2021).

Productivity, income and prices

For farmers, income and income diversification from their activities is one of the key questions. Previous studies have found that price fluctuations are one of the main problems for farmers (Teshome and Duerr 2018; Tobin et al 2016; Tobin and Glenna 2019). In addition to price volatility, low farm gate prices and increasing costs are problems (Jayasekhar and Hughes 2018). In general, cultivating niche crops may provide opportunity for earning price premium (Keleman and Hellin 2009; Tobin and Glenna 2019; Bisht 2021) but this is not always enough to solve the livelihood

problems of smallholders (Lanka et al 2017). If products are sold in international markets, price fluctuations my cause situations where price does not cover production costs (Lanka et al 2017). There are cases where farmers' associations regulate selling prices for a certain period, so that prices cover the costs and longer-term stability is provided for farmers (Sacchi et al 2019; Galli et al 2015; Kruijssen et al 2008). Price premiums over conventional crops could be offered also by contracts with processing industry and/or retailers (Tobin et al 2016). On the downside, increased bureaucracy and longer payment periods might reduce farmers' willingness to participate in such schemes (Tawk et al 2019). It has been found that some sustainability-oriented certification schemes do not sufficiently secure farms' economic viability (Bonisoli et al 2019). Integrated production, e.g. combination of crops and plantations could provide source of income for longer periods of a year, which is especially beneficial for smallholder family farms (Jayasekhar and Hughes 2018). In addition, access to new sustainable incentive schemes like carbon financing may open a new stream of income for farmers (Liu et al 2015). Also, it is important to improve farmers' management skills to reduce income variation due to production risks (Keleman et al 2013). Productivity could be hampered by diseases or due to lower yield potential of ancient varieties (Teshome and Duerr 2018; Sacchi et al 2019). However, diseases could also be a problem for conventional crops, thereby stimulating switch to alternative crops (Mithöfer et al 2017). Therefore, access to inputs and improved seeds remains important. Also, investments in tools and technologies might have a positive effect on profitability (Keleman 2013). However, it has been found that mechanisation could lead to higher income inequality.

Product quality and quantity

More diversified crop production inevitably results with more varied quality of the products and less products with identical quality parameters (Tesshome and Duerr 2018; Li et al 2014). Agro-biodiversity based food system are characterized by low standardization (Sachi et al 2019). On the other hand, through quality standards, the processing and distribution segments of the value chain often limit the number of varieties that are acceptable for marketing (Tobin et al 2016; Galli et al 2015), and sometimes, due to quality rejections, also the expected quantities cannot be delivered (Tobin and Glenna 2019). In several cases, internal (Sacchi et al 2019) or external (Veloz 2020; Friedman and McNair 2008; Bonisoli et al 2019) quality control and certification schemes have been used. Sometimes, producers' organization control production quantity internally to avoid oversupply and secure higher and more stable prices (Sacchi et al 2019). Higher value speciality products often have more strict quality standards (Jayasekhar and Hugher 2018; Wall et al 2019). Such quality certification schemes help to build reputation of producers' networks (Sacchi et al 2019). However, in some cases, the certification schemes have not proved successful (Veloz 2020). Inability to produce according to strict quality standards might demotivate farmers in participating in such schemes, while quality problems are often related to poor management skills (Tobin and Glenna 2019), production methods (Degato 2017) or inadequate storage conditions (Velmourougane and Bhat 2017). However, there are evidence on the effectiveness of certification awareness training (Mithöfer et al 2017) in improving the correspondence with the quality requirements. In some contexts, local consumer may be sceptical about the sanitary condition of production (Veloz 2020). This highlights the relevance of state food safety regulation and enforcement. For the consumers, in addition to safety, the second important quality characteristic is the taste of the product (Tobin 2016). For processing industry, another relevant aspect is the technical processability of the product (Kruijssen et al 2008).

Marketing options

Production of underutilized crops is viable only if farmers have market outlets for their produce. Due to the wide geographical coverage of reviewed papers, the marketing conditions should be

considered as context specific. In some cases, farmers may have poor access and/or high transaction costs to more profitable markets (Amaya et al 2020), and therefore be faced with limited market channels (Jayasekhar and Hughes 2018; Teshome and Duerr 2018; Mbosso et al 2020). Sometimes, farmers themselves might not be aware of the scale of regional, national or global markets and may lack marketing skills (Veloz 2020; Teshome and Duerr 2018; Lanka et al 2017; Velmourougane and Bhat 2017). Due to these constraints, often products are sold only in local markets, and at minimal prices (Veloz 2020; Tobin et al 2016; Tobin and Glenna 2019; Keleman et al 2013). Another marketing option could be via different middlemen (Jayasekhar and Hughes 2018; Teshome and Duerr 2018; Velazquez-Salasar et al 2021). In order to access markets of speciality products, new relationships are needed (Jayasekhar and Hughes 2018). Also, availability of labour and use of manual harvesting techniques may be useful in producing high value products (Keleman et al 2013). Still, the small market size and low willingness to pay for speciality products may remain a challenge (Taghikhah et al 2020). While small scale farmers may benefit from wide range of marketing strategies (Keleman et al 2013), too large variety of products may pose difficulties for marketing. Farmers are able to cultivate far bigger number of varieties than they are able to successfully sell (Tobin et al 2016). To this end, farmers' cooperatives could help farmers with coordinating production and marketing (Tawk et al 2019). Marketing can also be affected by gender differences: there is evidence that men prefer to sell to middlemen to save time, while women prefer to sell to end consumers to get a better price (Teshome and Duerr 2018). Sometimes, products may be sold in advance of harvesting season to overcome financial difficulties (Velmourougane and Bhat 2017; Tawk et al 2019).

Knowledge

The reviewed literature has analysed the role of knowledge from several perspectives. Lack of adequate training may be a constraint on productivity and income (Mbosso et al 2020; Teshome and Duerr 2018; Liu et al 2015; Wall et al 2019). Similarly, it is important to train farmers on the health and nutrition benefits of the products (Teshome and Duerr 2018; Rani et al 2018). Also, marketing, postharvest handling and storage knowledge is of utmost importance (Teshome and Duerr 2018). It has been found that farms that know their (industrial) customers' needs, and know how to produce such products, which characteristics enable downstream segments of value chains to generate value for end consumers (La Sala et al 2017). For cultivation of landraces and underutilized and neglected crops, traditional knowledge needs to be invigorated and leveraged (Vogliano et al 2021; Gaitan-Cremaschi et al 2017). Also, producers' associations and NGOs are expected to transfer knowledge and technical support to farmers (Sacchi et al 2019; Tobin and Glenna 2019). It has been suggested that better knowledge would help to reduce use of chemical inputs (Tawk et al 2019) and would help to select better varieties and seeds for cultivation (Onofre et al 2021; Bisht 2021).

Community and cultural identity

Cultivation of underutilized and neglected crops and landraces are not always purely economic decision. There are several aspects where local communities have a role and effect on farmers' decisions. When farmers are cooperating for production of certain products, local network members have power to decide which farmers to include to cooperation and which farmers to exclude (Sacchi et al 2019; Winans et al 2021). This may lead also to local social stratification (Tobin et al 2016; Tobin and Glenn 2019; Jayasekhar and Hughes 2018). It has been found that being neighbours or relatives increases willingness to cooperate (Veloz 2020). The specific crop may be regionally important, thereby being part of the regional identity and source of pride (Veloz 2020; Tobin et al 2016; Wall et al 2019; Velázquez-Salazar et al 2021; Peano et al 2015), which may lead to formation of bioregional farming communities (Friedmann and McNair 2008). While use to synthetic inputs may improve

product quality and productivity, such production methods may also erode cultural identity of such crops, an aspect to consider in development of value chains (Tobin et al 2016).

Post-harvest handling, storage and logistics

There are several aspects why post-harvest handling, storage and logistics are can be critical for some crops, especially for fruits and vegetables but also for cereals, coffee and cocoa. Handling and storage conditions may affect the quality of products (Sawadogo-Lingani et al 2021; Veloz 2020; Velmourougane and Bhat 2017; Sand Sava and Antofie 2019; Jayasekhar and Hughes 2018), and thereby poor conditions may lead to post-harvest losses (Mbosso et al 2020; Teshome and Duerr 2018) and reduction of income for farmers. Lack of storage capacity may also force farmers to sell their products immediately after harvesting when prices are low, however financial flexibility is also needed to wait for the better market prices (Keleman 2013). Problems with logistics may hinder access to more profitable markets (Keleman and Hellin 2009). Therefore, it is important that smallholders cooperate to establish necessary post-harvest and processing capacity (Maretta et al 2021; Jayasekhar and Hughes 2018).

Collaboration between farms

It has been outlined above that without collaboration, it is difficult for small scale farmers to participate in the value chains. However, often small-scale farmers do not cooperate (Teshome and Duerr 2018; Jayasekhar and Hughes 2018). The collaboration can be started informally (Sacchi et al 2019) but in more mature phase, it often takes place in the form of cooperative or producers' association (Lanka et a 2017; Kruijssen et a 2008; Jayasekhar and Hughes 2018; Mithöfer et al 2017). In either case, the governance of the collaborative network is a factor that motivates and keeps farmers committed (Sacchi et al 2019). However, it is not for granted that collective action always leads to positive results (Kruijssen et al 2008). Therefore, producer organizations may need assistance from national polices of NGOs (Mithöfer et al 2017). The roles of producer networks include upscaling production (Velázquez-Salazar et al 2021), marketing (Kruijssen et a 2008; Tawk et al 2019), processing (Degato 2017), and information transfer (Kruijssen et a 2008).

3.2.3 Processing industry

Technology

In agricultural production, availability of labour may give certain advantages for producing speciality products. However, in processing segment, reduction of labour use and mechanisation for capacity growth is creating advantages (Padulosi et al 2015; Sacchi et al 2019; Velmourougane and Bhat 2017). In some cases, traditional processing (e.g. baking) techniques are used to maintain the speciality of the product (Sacchi et al 2019). Local processing facilities might not always have the capacity to process all the raw material supplied produced by farmers (Mithöfer et al 2017), thereby posing limitations also for cultivation of crops. Generally, processing is considered to improve the quality of products and also to add value to primary crops (Degato 2017; Kruijssen et al 2008; Yamaguchi et al 2021). Some crops may need processing before they can be used (Bisht 2021). Processing facilities can also be owned by farmers' cooperatives (Veloz 2020) or individual farmers (Galli et al 2015).

Quality, quantity and seasonality of primary products

For the processing industry the raw material needs to correspond to certain quality, technical and sanitary standards (Teshome and Duerr 2018; Veloz 2020; Tobin et al 2016). The quality

requirements for local and international markets may differ (Veloz 2020). Therefore, low quality raw materials pose problems (Teshome and Duerr 2018; Veloz 2020). Also, sometimes the characteristics of specific variety are not appreciated by processing industry (Keleman and Hellin 2009; Wall et al 2019), while other varieties are well suitable for processing (Kruijssen et al 2008). This further highlight how important it is that both farmers and processing industry understand the necessary quality characteristics of raw agricultural products. At the same time, smallholders might have difficulties in fully understanding the importance of quality requirements (Tobin and Glenna 2019). Another set of problems is related to sufficient quantity and seasonality of production (Tobin and Glenna 2019; Keleman and Hellin 2009). Smaller scale processors might be able to cope with unstable supply and demand better but in any case, this results with inefficiency due to underutilized processing capacity (Galli et al 2015).

Differentiating from competition

One of the main reasons for processing stage to use underutilized or neglected crops or landraces lies in differentiating their products. The differentiation could be based on the sources of raw material supply (Degato 2017), both on the different variety and processing method of the product compared to standard industrial products (Sacchi et al 2019), corporate social responsibility claims of the processing industry companies (Tobin and Glenna 2019), or usage of certificates (Veloz 2020; Mithöfer et al 2017; Neilson and Pritchard 2007; Vermeulen and Kok 2012). Use of certificates usually necessitates cooperation with third parties like governmental agencies (Veloz 2020), NGOs (Mithöer at al 2017) or certifying organizations (Vermeulen and Kok 2012). Also, if certification is forced by industry, farmers may perceive it as a control over market access and economic rents (Neilson and Pritchard 2007).

Multi-stakeholder partnerships

Some of the examples of cooperation between farmers and processing industry include multi-stakeholder partnerships. The starting point for such collaborations is relationships management between firms in different segments of supply chain (La Sala 2017). Such partnerships are created to manage quantities as well a quality of raw materials for the processing industry (Sacchi et al 2019; Tobin and Glenna 2019). Such cooperation could also be a foundation for price agreements that satisfy both farmers' and processing industry ambitions and stabilise their relationships (Sacchi et al 2019).

3.2.4 Distribution

Coordination of supply

Since underutilized and neglected crops and landraces are often cultivated by small-scale farmers, their marketing activities need to be coordinated to achieve sufficient product volumes for processing industry or retailers. Underdeveloped and unstandardized value chains may become a limiting factor for primary production and marketing (Liu et al 2015). Marketing chains may have very different formations (Teshome and Duerr 2018), and managing all these might be too difficult task for small scale farmers due to human and physical capital shortages (Keleman et al 2013). It has been found that coordination of market activities with smallholders can be challenging because sometimes they operate according to different logic than value chains (Tobin and Glenna 2019). Therefore, middlemen, collector agents or wholesalers have an important role in securing high demand for the products through their networking and business skills (Wall et al 2019; Velmourougane and Bhat 2017) because the higher end of the value chain may be under the control

of few influential international companies (Lanka et al 2017; Friedmann and McNair 2008; Jayasekhar and Hughes 2018). The activities of collector agents may involve buying, assembling, transportation and selling to retailers and other consumers (Teshome and Duerr 2018). Supply coordination may take place in several different ways, and it is also dependent on the context of the region. In some cases, the middlemen operate informally, and their interaction with farmers is based on trust, friendship or family links (Veloz 2020).

Short supply chains

One of the main benefits for farmers and small-scale processors from participating in short supply chains lies in earning higher premiums by cutting out one or more segments of the value chain (Velazquez-Salasar et al 2021; Keleman and Hellin 2009; Keleman et al 2013; Teshome and Duerr 2018). Other aspects in favour of short supply chains include guaranteeing freshness of products and lower food miles (Zarbà et al 2019), and consumers' (also restaurants') habits to buy certain food products from local shops or farms (Galli et al 2015; Teshome and Duerr 2018). The outlets of short supply chains are typically local farmers' or speciality markets (Teshome and Duerr 2018; Tobin et al 2016; Keleman et al 2013), bakeries (Sacchi et al 2019; Galli et al 2015), and on farm sales (Galli et al 2015). Also, in order to shorten the distance between consumers and producers, alternative food networks could be developed (Lanka et al 2017).

Large-scale retailers

Large-scale retailers are one of the most dominant actors in value chains (Jayasekhar and Hughes 2018; Teshome and Duerr 2018), that establish safety and quality standards for the value chain and sometimes control even transnational value chains (Friedmann and McNair 2008). They are important market channels also for products based on neglected and underutilised crops and landraces (Sacchi et al 2019; Veloz 2020; Teshome and Duerr 2018). For retailers, one of the main motivations to work with such products is distinguishing themselves from competition (Tobin and Glenna 2019). Retailers may buy products from distributors or directly from farmers but often the low and unstable supply is a problem (Teshome and Duerr 2018).

HoReCa

The catering industry involves a large number of very diverse individual companies that could serve as market outlets for products based on underutilized and neglected crops and landraces (Galli et al 2015; Keleman and Hellin 2009). At the same time restaurants can have several useful functions for value chains – they may be considered as a showcase and outlet for local food products, but also a place for exchanging information and feedback between farmers and consumers (Li et al 2014). School meals are also an important part of catering business, which may include special characteristics for nutrition intervention and promotion of local food products (Padulosi et al 2015; Bisht 2021).

Markets

There are different potential markets for underutilized and neglected crops. It has been established that speciality markets offer higher income for farmers than intermediary markets (Keleman et al 2013), while distributors may capture the highest marketing margins (Teshome and Duerr 2018; Jayasekhar and Hughes 2018). Also, for some products, there is an increasing demand in urban markets (Keleman et al 2013). In some cases, landraces are part of national cuisines and traditions, thereby markets for landrace-based products are already established (Keleman et al 2013). For some products, there is a high demand in foreign markets, and therefore value chain development focuses on export (Maretta et al 2021), which in some regions may be also informal (Veloz 2020).

Quality, quantity and seasonality of primary products

Sufficient volume, stability of supply and volatile quality are problems for distribution segment, like for the processing segment of the value chains (Teshome and Duerr 2018). While for the processing industry, internal quality characteristics of raw materials are the most important, for distribution segment, the external quality (size, lack of damages, cleanliness) parameters prevail (Tobin and Glenna 2019). The seasonality of supply is one of the reasons why distribution segment might not profit from selling products based on underutilized and neglected crops and landraces (Tobin and Glenna 2019). In some cases, traders have been able to stabilize supply for retailers by stocking enough produce for longer periods (Mbosso et al 2020). Another coping mechanism with seasonality is adjustment of consumption to seasonal patterns of supply, however, seasonality may cause also higher price fluctuations (Teshome and Duerr 2018). In the international markets, product quality is the most important characteristic that determines the product price (Velmourougane and Bhat 2017).

3.2.5 Consumers

Quality, certificates, labelling and traceability

It is important to create trust among consumers towards the products, especially when it comes to launching new products on the market. The quality of a products needs to be defined and also guaranteed for consumers (Friedman ad McNair 2008; Vermeulen and Kok 2012; Velmourougane and Bhat 2017; Velazquez and Salazar 2021). To create new markets for new products, certification and labelling of origin, quality and production methods, e.g. organic (Friedman and McNair 2008; Taghikhah et al 2020) or sustainable (Bisht 2021; Winans et al 2021) is quite common. However, due to increasing number and complexity of certificates and labels and competition between these (Vermeulen and Kok 2012; Taghikhah et al 2020), it is becoming questionable to what extent these inform consumers (Friedman ad McNair 2008) affect consumers' willingness to purchase and willingness to pay (Keleman and Hellin 2009), and to what extent these schemes benefit producers (Keleman and Hellin 2009; Friedman ad McNair 2008). Such confusion may lead to reduced credibility of certification systems and reduced consumer commitment (Vermeulen and Kok 2012). In addition to formal quality assurance systems, through social innovation, it is also possible to establish informal systems to assure product quality for consumers (Sacchi et al 2019). Therefore, local short supply chains could be de facto transparent also without formal quality assurance schemes, while global chains need to develop and/or use formalized certification and labelling schemes (Galli et al 2015).

Consumer awareness and preferences

Consumer awareness and preferences are important factors in transition to sustainable value chains (Taghikhah et al 2020). The demand for products based on landraces, underutilized and neglected crops might be low for several reasons – these products may be used as accessory foods rather than staples (Mbosso et al 2020); consumers may have lost habit of consumption of these products (Amaya et al 2020) and might consider them old-fashioned (Vogliano et al 2021) or not tasty (Andersen 2012; Tobin et a 2016); they might be unaware of the nutritional and/or medicinal qualities of the products (Amaya et al 2020); also, consumers may be unaware of and therefore not value the agroecology of certain products (Tu et al 2021); the products may be available only seasonally (Teshome and Duerr 2018); the value chains may focus on development of exports thereby neglecting the local consumers (Maretta et al 2021). On the other hand there are factors that increase consumer interest and demand – old genotypes may have interesting quality properties

(Passafiume et al 2021); there is an increasing consumer interest towards nutraceutical and phyto-terapeutic qualities of products (Zarbà et al 2019; Teshome and Duerr 2018; Velazqez-Salazar et al 2021); consumers are becoming more aware about ethical, environmental and biodiversity problems that increases their willingness to purchase such products (Tu et al 2021; Galli et al 2015); modern food production methods no longer meet the health needs of consumers (Bisht 2021; Velmourougane and Bhat 2017); in global value chains consumers are willing to pay premiums for fair trade (Tu et al 2021). Therefore, it has been found that awareness raising among consumers is of paramount importance for the value chains of underutilized and neglected crops and landraces (Teshome and Duerr 2018; Devaux and Ordinola 2019; Taghikhah et al 2020; Sand Sava and Antofie 2019).

Cultural traditions and familiarity to products

Cultural traditions also play a major role in consumption of landraces and underutilized crops. Some countries and regions have culinary traditions and recipes that include such crops (Galli et al 2015; Tawk et al 2019; Elia and Santamaria 2013; Sand Sava and Antofie 2019). Consumption of some foods may be related to religious values and festivities (Teshome and Duerr 2018; Wall et al 2019). Also, some crops and plants may be culturally important (Wall et al 2019; Keleman et al 2013; Amaya et al 2020). Some crops and food related traditions can be part of historical memory and identity of consumers, and therefore consumers have high willingness to purchase such products (Zarbà et al 2019; Rani et al 2018; Friedman and McNair 2008). Therefore, consumption of certain products may reaffirm consumers' regional identity (Veloz 2020; Tawk et al 2019). Therefore, even in the context of urbanization, geographical indications and re-localization of food production may have relevance for urban consumers (Galli et al 2015; Vogliano et al 2021).

Marketing strategies

Development of value chains for underutilized and neglected crops entails also increasing consumer awareness (Maretta et al 2021; Velázquez-Salazar et al 2021), trust between producers and consumers (Galli et al 2015) and developing value proposition for consumers (Liu et al 2015) to change their mindsets about the products (Velázquez-Salazar et al 2021). Different channels are used for this: direct social relationships (Galli et al 2015), social media and new technology (Liu et al 2015; Maretta et al 2021), conventional media (Maretta et al 2021)

Cookability

In addition to quality parameters and consumer awareness the cooking qualities of products like ease of preparation, appearance and organoleptic features are important determinants of consumption (Andresen 2012; Liu et al 2015). In some cases, collaboration with well-known chefs in developing new recipes have helped to strengthen the demand for products (Elia and Santamaria 2013).

3.2.6 Institutions and policy

The role of institutions and policy is to create an enabling environment for development of value chains that support biodiversity. Thereby, institutions and policy have connections with most of the themes that emerged under each of the value chain segments.

Supporting organisations

Development of value chains for landraces, underutilized and neglected crops and varieties often involves several organizations that may have important roles depending on their capacities and local institutional structures. In addition to their expertise their role is acting as collaborative platforms that bring together different actors in and around value chains. These may include universities (Sacchi et al 2019; Kruijssen et al 2008), associations (Sacchi et al 2019), consortiums (Sacchi et al 2019), NGOs (Tobin et al 2016; Tobin and Glenna 2019; Friedmann and McNair 2008; Mithöfer et al 2017), networks (Li et al 2014), research organizations (Li et al 2014; Kruijssen et al 2008), foundations (Friedmann and McNair 2008; Kruijssen et al 2008), societies (Kruijssen et al 2008), and producer organizations (Mithöfer et al 2017).

Breeding programs

Breeding programs are needed to conserve landraces, develop varieties that are resistant to changing environmental conditions and secure long-term food security. Landraces can be considered as reservoirs of genes that plant breeders need for crop improvement programs, therefore conserving landraces is important (Tawk et al 2019). It has been suggested that crop-breeding efforts should be broadened beyond focusing only on grain yield (Keleman et al 2013). It is necessary to develop breeding programs that include germplasm collection, genotype selection, and meet breeders' requirements (Maretta et al 2021). Breeding programs may be joint efforts of the whole sectors of agriculture (Li et al 2014). Crop or variety improvement for the future may entail e.g. adaptation of varieties for local conditions (Li et al 2014), improving drought-resistance (Liu et al 2015), and reduction of yield variability (Zander et al 2016).

Governance

No single actor or value chain segment can preserve certain variety or develop value chain for its products (Velázquez-Salazar 2021). Therefore, value chain governance is of importance. However, the effective governance arrangements are context specific, depending on the institutions of specific country or region. There are examples of hybrid governance models where private sector, state and civil society work together (Tobin and Glenna 2019). In some contexts, the state has links with all the value chain actors and can thereby take the role of facilitator (Keleman and Hellin 2009). In such cases, the actors need to handle complex nexus of power relations (Jayasekhar and Hughes 2018), and again, sometimes governments need to balance the interests of different parties (Mithöfer et al 2017). While this is feasible at local, regional and state levels, self-governance difficulties are one of the shortcomings of international value chains (Vermeulen and Kok 2012).

Food security

Landraces, underutilized and neglected crops may be important for food security of local communities by diversifying food crops (Maretta et al 2021), improving nutrition (Teshome and Duerr 2018), reducing dependence on synthetic fertilizers and plant protection (Fang and Zhu 2014), and utilizing wild food resources (Bisht 2021).

Income and investment support

Governments may support development of value chains or value chain segments through different instruments. Such instruments may include investment grants (Maretta et al 2021) or subsidised credit (Garrett and Rausch 2015; Jayasekhar and Hughes 2018) to accelerate technology uptake, investment in infrastructure (Garrett and Rausch 2015), income insurance (Garrett and Rausch 2015), provision of basic farm facilities for smallholders (Velmourougane and Bhat 2017), technical

and marketing assistance (Jayasekhar and Hughes 2018), or subsidies that partially compensate production costs (Tawk et al 2019).

Research and development

Academic literature stresses the relevance of multidisciplinary and integrated research and development that can itself support developing biodiversity friendly value chains (Elia and Santamaria 2013). The research agenda may include identification of new value chain outlets (Tobin et al 2016; Devaux and Ordinola 2019); livelihood, food security, diet diversity (Padulosi et al 2015); and additional benefits beyond producing crops itself (Liu et al 2015).

Farmers' collaboration and cooperation

Farmers' cooperatives and collective action are needed to upscale production, improve quality and create more value. Collective action can decrease transaction costs and improve functioning of the value chain (Kruijssen et al 2008). Therefore, in general, efforts should be made to strengthen farmers' collaboration (Teshome and Duerr 2018). Organized groups of farmers have better access to external financing that is needed for inputs, equipment and technology (Keleman et al 2013). However, collective action is not always successful nor has to be so (Kruijssen et al 2008), and farmers tend to prefer the structures they have built socially themselves (Velázquez-Salazar et al 2021).

Strategic planning

Successful development of value chains needs long-term commitment (Keleman and Hellin 2009). Lack of continuity of public policies due to government changes poses a risk for the successful value chain development (Velázquez-Salazar et al 2021). Therefore, strategic planning is needed that encompasses all the aspects of successful value chains (Zander et al 2016; Velázquez-Salazar et al 2021). In addition, it has been suggested that value chains itself have a limited effect on biodiversity conservation, thereby in addition to market-oriented solutions, complementary conservation strategies should be planned and executed (Tobin et al 2016).

Trade policy

Trade policy has multiple roles in protecting and enhancing biodiversity friendly value chains. Through international trade relationships, new markets can be created for producers of certain country(ies) by creating price advantages compared to other countries (Tu et al 2021) or creating price disadvantages for certain products (Zander et al 2016). Also, international agreements could pave the way for establishing standards of more sustainable agricultural models (Friedman and McNair 2008). On the other hand, germplasm trade may be restricted to protect intellectual property rights (Andersen 2012). Also, it has to be noted that international trade may facilitate spread of pests and diseases (Onofre et al 2021). Thereby phytosanitary regulations and controls need to be established.

Knowledge transfer

Production, processing and consumption of products based on landraces or underutilized and neglected crops requires certain knowledge. Therefore, knowledge transfer is important to enhance creation of such value chains (Velmourougane and Bhat 2017; Devaux and Ordinola 2019; Sacchi et al 2019). It has been noted that mass awareness programs for all involved stakeholders are needed, specifically in relation to international requirements for sustainable and good quality products (Velmourougane and Bhat 2017). On the other hand, socially innovative ways of knowledge transfer are needed to enhance local animation, creativity and capacity building in local communities (Sacchi et al 2019).

Market support measures

Market support measures may entail different labels related to origin or geographical indication of production (Friedman and McNair 2008). Governments may facilitate also development of private voluntary certification systems (Vermeulen and Kok 2012). In addition, they may include different services – e.g., collection, storage and transportation of products to warehouses and processing facilities (Velmourougane and Bhat 2017). It has been suggested that combined market and information-based policy is more effective than stand-alone individual policies (Taghikhah et al 2020).

Protection of genetic diversity

Biodiversity conservation and protection of genetic diversity requires cooperation of many value chain members (Wall et al 2019) but also external actors like ministries and research institutes who manage materials, seed banks, research orchards, and document genetic diversity for the species (Wall et al 2019). Protection of species is based on both international tools (conventions, protocols, strategies) and national laws that enforce necessary regulations (Velázquez-Salazar et al 2021).

Regulations

Through regulations, governments may have positive or adverse effects on the development of biodiversity friendly value chains. By accepting non-governmental food audits by food regulation, government may open road for developing private standards, which may evolve beyond minimum standards established by the state, and therefore itself become benchmark standards for the government (Friedmand and McNair 2008). In order to support creation of certification schemes governments can protect intellectual property rights of certifying bodies and at the same time (conditionally) ensure fair distribution of added value in the value chain (Sacchi et al 2019). Also, some regulations may have adverse effects on biodiversity, e.g. biofuel blending mandates that affect relative profitability of competing crops (Zander et al 2016).

4. Conclusions

Increasing biodiversity in crop value chains is a complex issue that need consideration of all value chain segments, relevant value network agents, as well as institutional and policy environment. The underlying assumption of this study was that cultivation of underutilized and neglected crops and landraces will have positive effect on biodiversity. However, value chains need to be developed for their uptake. It is important to ensure that quality seeds are available for cultivation of these crops, and also the varieties are further developed to cope with different stresses that arise from environmental changes. For farmers, the main motivation for cultivation of these crops is income, however, cultural and societal factors also play a role but are context specific. In order to generate income, the products need to be marketed. Often, farmers take advantage of shot supply chains and sell the products directly to customers in different markets or HoReCa sector. In order to sell the products to processing industry or retail sector, the main challenge lies in achieving sufficient volume and quality of the products. Here, the quality requirements of processing industry and retailers are different. For processing, the crops need to have certain (internal) properties, while for retailers, the appearance of the products is more important. In either case, it is necessary that consumers appreciate the taste of the products. When crops and products are culturally embedded, it is easier to market these for end consumers. Otherwise, the products are new to consumers and need to be introduced, which is a time-consuming process.

5. Policy recommendations

It is important that governance structure and strategic planning is established for promoting underutilized and neglected crops and landraces, and creating value chains for the related products. The governance should consider all the segments of the value chain, as well as relevant supporting organisations and needed policy instruments. The main segments and processes that might need policy intervention are:

- Protection of genetic diversity, breeding programs and seed production for the considered crops.
- Increasing farmers knowledge about cultivation of the considered crops, their characteristics that are important for processing industry and consumers.
- Promoting and supporting collaboration of farmers to increase volume and quality of the products, and also collaborations between farmers' cooperatives, processing industry and retailers.
- If necessary in local market conditions, improving accessibility to financing investments into post-harvest handling, storage and processing.
- Awareness raising among consumers on the relevance of the considered crops from biodiversity, cultural and nutritional aspects, as well as about how these crops and products can be used for cooking and meals.
- Market development for considered crops and products through institutional catering and public procurement.

6. Market related and practical recommendations

Farmers are often unaware about the potential market size of underutilized and neglected crops and landraces. Therefore, it is important to improve knowledge about potential products, markets for these and also inform farmers and other value chain segments. Three general types of market channels could be considered for these crops – 1) short supply chains, 2) conventional supply chains involving processing industry and/or retailers, 3) international supply chains. Development of value chains does not rule out any of these but considering the potential product volume constraints, the value chain development could focus one or two of these, not necessarily on all these at the same time. Depending on the focus of value chain development, market related knowledge of the stakeholders should be improved. It is very important that the value chain actors understand the quality requirements and know how to provide outputs that correspond with the requirements of the next value chain member for whom this output is an input for further processes and activities.

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8. Annex

Table 9: Crops and countries or regions in reviewed papers

Author	Crop	Country
Amaya et al 2020	Chaya	Guatemala
Andersen 2012	Ricebean	India, Nepal
Bisht 2021	Herbs, rice, wheat, potato	India
Bonisoli et al 2019	Banana	Ecuador
Buchwaldt, Richards 2004	Fruits, potato, winter cereals, barley, oat, flax, lentil, chickpea, Brassica napus	Canada
Degato 2017	Coffee	Ethiopia
Devaux, Ordinola 2019	Potato	Peru, Bolivia, Ecuador
Elia, Santamaria 2013	Vegetables	Italy
Fang, Zhu 2014	Fruits	China
Friedmann, McNair 2008	Avocado	Mexico, Canada
Gaitan-Cremaschi et al 2017	Soybeans	Netherlands
Galli et al 2015	Wheat	Italy
Garrett, Rausch 2016	Soybeans	Brazil
Iocola et al 2018	Vegetables	Italy
Iocola et al 2021	Cereals	Italy
Jayasekhar, Hughes 2018	Plantation crops	India
Keleman et al 2013	Maize	Mexico
Keleman, Hellin 2009	Maize	Mexico
Kliem, Sievers-Glotzbach 2021	Vegetables	Germany, Austria, Switzerland
Kruijssen et al 2008	Fruits	India, Thailand and Indonesia
La Sala et al 2017	Grapes	Italy
Lanka et al 2017	Coffee	India
Li et al 2014	Maize	China
Liu et al 2015	Herbal tea	China
Maretta et al 2021	Taro	Indonesia
Mboso et al 2020	Fonio, groundnut	Mali
Mithöfer et al 2017	Cocoa	Indonesia, Peru, Cameroon
Neilson, Pritchard 2007	Coffee	India
Onofre et al 2021	Potato	Georgia
Padulosi et al 2015	Minor millets	India
Passafiume et al 2021	Apples	Mediterranean
Peano et al 2015	Peas, plums, tomatos, apples, lentila, beans, caper, asparagus, garlic	Italy
Pedersen 2020	Cabbage, turnip, peas, beans	Denmark, Norway, Sweden
Rani et al 2018	Mungbean	Pakistan, Uzbekistan
Sacchi et al 2019	Wheat	Italy
Sand Sava, Antofie 2019	Potato, beans, cabbage, onion, garlic, parsley, dill, tarragon, thyme and basil, apples, fruits	Transilvania
Sawadogo-Lingani et al 2021	Sorghum	Burkina Faso, Mali, Ghana, Benin, Togo, Nigeria, Ivory Coast

Zander et al 2016	Legumes	Europe
Zarba et al 2019	Wild leafy plants	Italy
Taghikhah et al 2020	Grapes	Australia
Tawk et al 2019	Wheat	Lebanon
Teshome, Duerr 2018	Vegetables	Ethiopia
Tobin et al 2016	Potato	Peru
Tobin, Glenna 2019	Potato	Peru
Wall et al 2019	Sweet chestnut	Turkey
Vanlauwe et al 2019	Legumes	Sub-Saharan Africa
Velázquez-Salazar et al 2021	Maize	Mexico
Velmourougane, Bhat 2017	Coffee	India
Veloz 2020	Açaí	Brazil, Colombia
Vermeulen, Kok 2012	Coffee	Netherlands
Winans et al 2021	Almonds, grapes	USA
Vo Hong Tu et al 2021	Rice	Vietnam
Vogliano et al 2021	Wild foods	Solomon Islands
Yamaguchi et al 2021	Bacuri	Brazil