Deliverable 2.4

Selection of agent-based modelling tools suitable for agri-food value chains

Project Acronym	**BIOVALUE**
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Executive Summary

Task 2.4 synthesized the results of preceding tasks 2.1 Reviewing of agri-food value chain tools; 2.2 Reviewing of agent-based modelling tools; and 2.3 Reviewing of biodiversity in the value chain to summarize the general value chain framework, the key value chain segments and environmental elements, as well as characteristics of value chain agents and relationships between agents. This information could be used in developing questionnaires for data collection in order to characterize value chain agents and their interrelationships in specific details. Also, crucial points to keep in mind in the technical execution of agent-based model were outlined.

It was established that from the different approaches of value chain analysis, functional analysis is most appropriate for the BioValue project and tool development. Functional analysis produces common typologies, flow charts, considers sub-chains, establishes geographical boundaries, and considers temporal dimension, all of which are relevant and functional inputs for development of any model.

Task 2.1 reviewed properties of underutilized crops from production, environment, processing and consumption perspectives. Literature review conducted in Task 2.3 confirmed some of these factors and added additional ones. These properties are relevant both, from the value chain development, but also value chain modelling perspectives.

FAO Sustainable food value chain framework summarizes well the concept and context for the development of value chains for underutilized crops. The review of agent-based modelling tools outlined two main interaction arenas for agents. First, agents interact with other agents. In other words, business in the segments of the value chain interact with business within their segment and also with businesses in different segments of the value chain. Second, agents also interact with environment. Here, the environment should be considered in a wider sense, as an enabling environment that comprises economic, natural environmental and societal domains.

Considering the actors in the extended value chain and also literature review conducted in Task 2.3, it is advisable to include in the model explicitly input segment that focuses on production and distribution of seeds for underutilized crops. Also, interactions with natural environment and organizations that may have a role in value chain development should be considered. Another aspect to consider is to enable flexibility for flows of products, money and information between value chain segments.

The main critical aspects of each value chain segment were outlined, which may have relevance for developing BioValue agent-based model. Also, the characteristics and preferences of agents, their key drivers and linkages between them were outlined for the model development.

For the technical model building, it is advisable to start from more simpler value chain representations and interactions between agents, however, if it foreseen that step-by-step, more complex setup is achieved, it might be advisable to select more complex and comprehensive technical tools from the start on.

Table of Contents

Table of Contents

List of Tables

List of Figures

Abbreviations and Acronyms

BioValue	BioValue project – Fork-to-farm agent-based simulation tool augmenting BIOdiversity in the agri-food VALUE chain
FAO	Food and Agriculture Organization of the United Nations

1. Introduction

The developed behavioural model of the BioValue project is based on an agent-based approach where each agent has their own characteristics and preferences. Therefore, it is important to identify key characteristics, drivers and linkages of all value chain actors. Application of machine-learning will allow the proper and rapid parametrization of the model. Task 2.4 provides the basis for the characteristics of each agent in the agri-food value chain. For this, Task 2.4 reviews and summarizes the key results of the three preceding review tasks of the project that build the foundation for development of the BioValue tool: Task 2.1 Reviewing of agri-food value chain tools, Task 2.2 Reviewing of agent-based modelling tools, and Task 2.3 Reviewing of biodiversity in the value chain.

2. Key results from BioValue reviews

2.1 Review of agri-food value chain tools

The task 2.1 encompassed a comprehensive review of several topics, which are crucial for selecting tools and approaches in the BioValue project. This review included: conceptual and analytical frame work of value chains; generalized up-stream and down-stream of value chains; value chain modelling tools for production process, investment planning, quality control, price transmission and product delivery channels; causes and conditions that the consumption and cultivation of numerous crops (legumes, vegetables) were altered or completely eliminated; cultivation and consumption patterns of foods of interest with an assessment of consumers' needs; healthy and environmentally friendly foods; the causes of biodiversity decline and factors that could be relevant for increasing biodiversity in the future.

There are numerous well-defined guidelines for value chain analysis that have been developed by international organizations and/or projects. These guidelines allow to analyse value chains from institutional/functional, economic/financial, social, and environmental perspectives (Table 1). From these perspectives, the functional value chain analysis (Figure 1) is most appropriate approach for the BioValue project and for the development of the BioValue tool. Functional value chain analysis encompasses products, relevant actors, their functions, flows of products, finances and information, and governance. These are all crucial elements in the process of the development of value chains for underutilized and neglected crops and landraces (BIOVALUE – D2.2; BIOVALUE – D2.3). Functional analysis produces common typologies, flow charts, considers sub-chains, establishes geographical boundaries, and considers temporal dimension, all of which are relevant and functional inputs for development of any model.

Table 1: Guidelines with Their Area of Interests on Value Chain Analysis[Source: BIOVALUE – D2.1 (2022)]

The Guidelines	Institutional/ Functional Analysis	Economic/ Financial Analysis	Social Analysis	Environmental Analysis: Impact on Biodiversity
1.ILO-Value Chain Development for Decent Work(2021)				
2.VCA4D:Value Chain Analysis for Development(2018)				
3.ACIAR- Australian Center for International Agricultural Research(2016)				
4.GTZ/GIS-Guidelines For Value Chain Selection(2015)				
5.FAO- Developing sustainable food value chains(2014)				
6.FAO VC Analysis for Policy Making(2013)				
7.UNIDO- United Nations Industrial Development Organization(2011)				
8.IIED - International Institute for Environment and Development(2008)				
9.M4P -Making VCs Work Better for the Poor(2008)				
10.USAID – United State Agency International Development(2008)				
11.GFU-Promoting Value Chains of Neglected and Underutilized Species(2008)				
12.CIAT - Centro Internacional de Agricultura Tropical(2007)				
13.FAO – Rapid Appraisals(2007)				
14.CIP-International Potato Center(2006)				

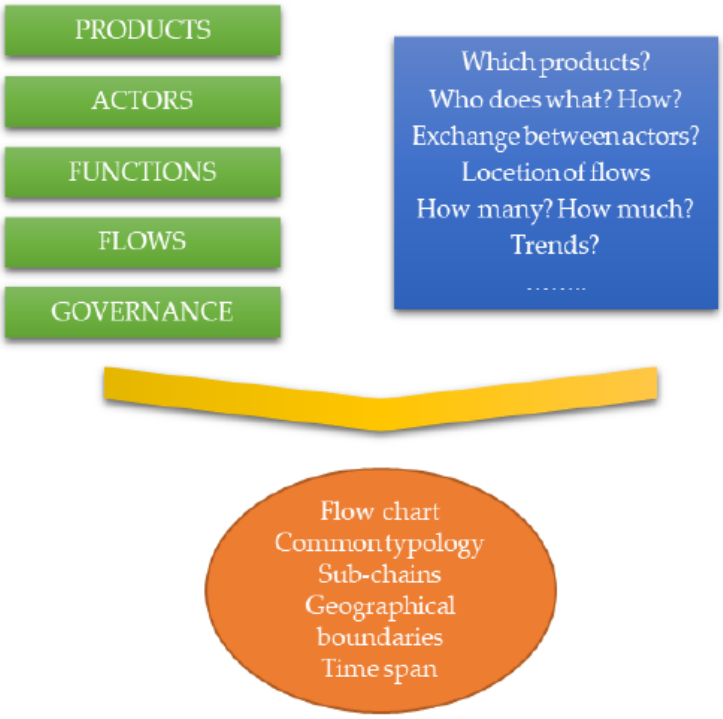

Figure 1: Functional Analysis of Value Chain Functional Analysis of Value Chain [Source: European Commission (2018)]

Also, Task 2.1 reviewed properties of underutilized crops from production, environment, processing and consumption perspectives (BIOVALUE – D2.1). Literature review conducted in Task 2.3 confirmed some of these factors and added additional ones (BIOVALUE – D2.3). These properties are relevant both, from the value chain development, but also value chain modelling perspectives.

Production

- Problems with production and harvesting, yield, land use, seeds availability, processing of seeds.
- Agronomical traits, germplasm collection, genetic factors, limited number of species used as food.
- Poor economic competitiveness of underutilized compared to staple crops.

Environment

- Biotic factors: insects, diseases, and weeds.
- Abiotic issues: temperature, soil fertility, waterlogging, drought.

Processing

- Inefficiency in producing, storing, and processing of these crops.
- Marketing constraints, short shelf life, especially in case of vegetables.

Consumption

- The lack of sound baseline data on the nutritional and health-protective/promoting properties of these foods.
- Lack of culinary skills for the preparation of products based on these plants.
- Unaccustomed taste of these foods, non-popular recipes.
- Negative associations with a poor rural lifestyle and low social status, negative cultural stereotypes against these traditional foods, like “this is what poor people eat”.
- Presence of toxins and allergenic compounds.

Policy recommendations

- Use beneficial crop traits and enhance desirable agronomic traits.
- Improve seed availability and organise seed exchange events by local actors or central government.
- Develop ways to eliminate potentially toxic and allergenic substances.
- Educate consumers.
- Use food systems approach for policy making.
- Certification and labelling for quality and other parameters.
- Increase taxes on environmentally unfriendly food.
- Change diets towards more plant-based.
- Educate parents and children on nutrition and environmental impact of food habits.
- Introduction of novel food recipes prepared on underutilised crops by food festivals and exhibitions.
- Farmer supports on cost of production of local seeds users – input subsidies and income transfers.

- Development of contracting farming between processors, retailers and farmers of underutilised crops.

2.2 Review of agent-based modelling tools

FAO Sustainable food value chain framework summarizes well the concept and context for the development of value chains for underutilized crops (Figure 2). Core value chain comprises production, aggregation, processing and distribution segments. In the extended value chain, one needs to consider upstream segments like input provision, and services (also financing). Core and extended value chain produce products for national and international markets. National market with the mentioned value chain but also with environmental and societal elements provides national enabling environment, while adding international markets necessitates consideration of global enabling environment. At the same time, it is crucial to consider that societal and environmental elements are not limited by country borders, and they are part of both, national and global enabling environments, and they can be the same for both environments, but they can also be different, depending on the context and similarities between countries. Figure 2 also highlights that for sustainability, economic, (natural) environmental and societal elements of the overall enabling environment need to be considered and balanced.

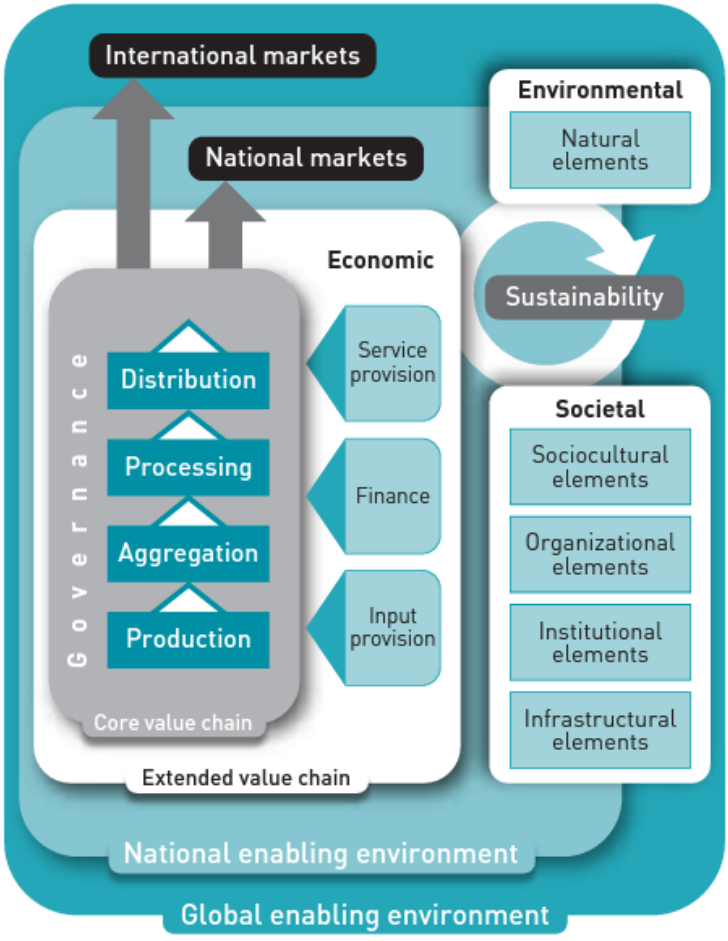

Figure 2: Sustainable food value chain framework [Source: FAO (2014)]

The review of agent-based modelling tools (BIOVALUE – D2.2, 2022) outlined two main interaction arenas for agents (Figure 3). First, agents interact with other agents. In other words, business in the segments of the value chain interact with business within their segment and also with businesses in different segments of the value chain. Second, agents also interact with environment. Here, the environment should be considered in a wider sense, as an enabling environment that comprises economic, natural environmental and societal domains (Figure 2).

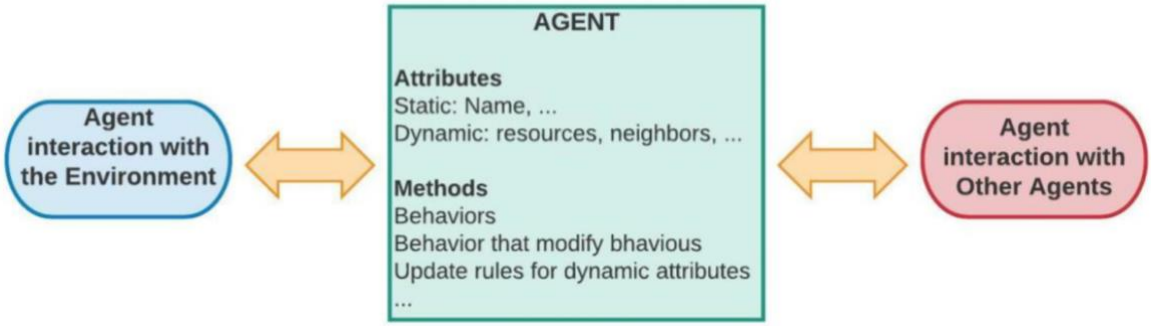

Figure 3: The agent and its interactions [Source: BIOVALUE – D2.2 (2022)]

The environmental factors are further reviewed in Task 2.3. Based on BIOVALUE – D2.3 (2022), the elements of natural environment that could be considered are related to the quality of land and the area of the land available for cultivation of underutilized crops. According to the literature, such crops are often cultivated on marginal land. Also, biotic stress factors could be considered. It would be relevant to simulate also the effects of crop production and crop selection on biodiversity and natural environment, but it must be assessed whether this is feasible in the scope if the BioValue project.

Sociocultural elements of the enabling environment could consider whether particular underutilized crops are known in the study region both, for farmers and for consumers. If the specific crops are culturally embedded, then there is not so much need for awareness raising and market creation, compared to the situation where the specific crop is totally unknown in the region. Organizational elements may involve the existence of farmers' cooperatives and networks that could be the foundation for collaboration for growing underutilized crops. Also, these elements could involve so called supporting organizations for value chain development, which can exist in different forms. Institutional elements may involve the level of trust among value chain actors of the specific region, the level of formality and informality of their relations, existence of certification and quality management schemes. Infrastructure might consider the level of post-harvest handling, storage and logistics. In some regions, these elements are lacking, and therefore losses in product volume and quality are significant.

Figure 4 presents a tentative general overview of the BioValue agent-based model. Considering the actors in the extended value chain (Figure 2) and also literature review conducted in Task 2.3 (BIOVALUE – D2.3, 2022), it is advisable to add to the model explicitly input segment that focuses on production and distribution of seeds for underutilized crops. Also, interactions with natural environment (partly included as climate in the agricultural producers' segment) and organizations that may have a role in value chain development should be considered. Another aspect to consider is to enable flexibility for flows of products, money and information. E.g., farmers may sell some products directly to consumers or retailers, or processors may sell directly to food retailers. Task 2.3 (BIOVALUE – D2.3, 2022) outlined three general market channels – short supply chains, conventional

supply chains and international supply chains. Farmers' markets and HoReCa companies are often part of short supply chains and should be considered as part of the food distributors' segment.

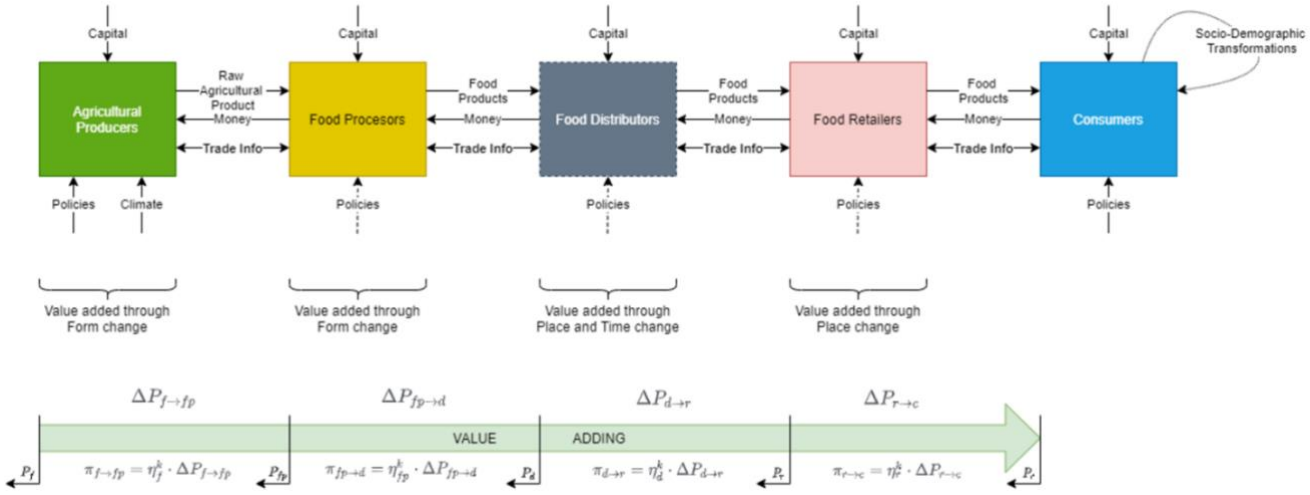

Figure 4: Tentative general overview of the BioValue agent-based model [Source: BIOVALUE – D2.2 (2022)]

2.3 Review of biodiversity in the value chain

Review of biodiversity in the value chain considered value chain segments inputs, farmers, processing, distribution, consumers, as well as institutional and policy environment. Detailed analysis of the literature is provided in BIOVALUE – D2.3 (2022). In the following, main critical aspects of each element are outlined, which may have relevance for developing BioValue agent-based model.

Inputs

- Seeds are a critical input.
- Marginal and small land plots are suitable for low input farming.

Farmers

- Income is a critical factor for farmers' decision making.
- Production systems often utilize traditional agroecological practices – related to marginal land, low input farming and indigenous or traditional knowledge.
- Delivering stable quantity and quality is a challenge for small-scale farmers.
- Underutilized crops are often related to local culture and traditions but it is questionable if consumers are aware of these.
- Collaboration of small-scale farmers is necessary for post-harvest handling and marketing.
- Knowledge is an important input for production and marketing

Processing

- Handling inputs of variable quantity and quality is a challenge for technology in the processing industry.
- Partnerships with farmers or middlemen could be used to secure volume, quality and price of products.
- Differentiation from competitors is one of the drivers for processing industry to work with underutilized crops.

Distribution

- Main market channels are short supply chains, large-scale retailers, HoReCa, and in some cases international value chains.
- Coordination of quantity and quality of products is a challenge for distribution segment as well as for the processing industry.

Consumers

- Awareness about the products is a key factor for willingness to purchase – affected by the cultural traditions, certification, marketing approaches.

Institutions and policy

- Holistic approach needed on value chain development that addresses all the segments.
- Long term strategic planning and governance are needed.

2.4 Agents, their drivers and linkages

One of the main research questions for Task 2.4 is related to the characteristics and preferences of agents, their key drivers and linkages between them. In the following, an overview of the agents in each of the value chain segments are given.

Input suppliers

Characteristics and preferences

- Usually providers of seeds of underutilized crops are not commercial enterprises.
- They can be NGOs, universities, research institutes, gene banks or their associations and consortiums.
- Sometimes farmers themselves become seed producers, if the institutional environment creates supportive environment for this.

Key drivers

- For NGOs, universities, research institutes, gene banks or their associations and consortiums – mission or duty set by the state; their activities can be partially financed by the state.
- For farmers-seed producers the main driver is additional income and profit.

Key linkages between agents

- Seed producers sell seeds to farmers.
- NGOs, universities, research institutes, gene banks work on breeding and reproduction programs to improve the traits of varieties and make them available for farmers.

Farmers

Characteristics and preferences

- Farmers already exist in pilot areas of the BioValue project – in the model, multiple farmer-agents are needed that correspond to actual size and production distribution in the pilot area.
- Some or all farmers may partly change their current crop selection – to manage risks, no one will fully convert to pilot crops.

Key drivers

- Profit seeking.
- Risk management.

- Utilization of marginal land.
- Community interest and cultural identity.
- Policy measures – subsidy for specific crops, crop diversification mandates.
- Demand from processing industry or distributors.

Key linkages between agents

- Farmers buy seeds from seed producers, they may be seed producers themselves.
- Collaboration with other farmers to organize production and achieve reasonable scale, in some cases also joint post-harvest handling, processing and marketing.
- If processing industry is missing in the pilot region, farmers have larger incentive to start processing themselves.
- Farmers sell primary produce to processors.
- Some farmers may sell primary or processed products directly to distributors – retailers, specialized shops, HoReCa.
- Some farmers may sell primary or processed products directly to consumers – farm shops, farmers' markets, direct sales.
- Processors and distributors may have contractual agreements with farmers to regulate quantities, quality and payment schemes.
- NGOs, universities, research institutes, or extension service might advise farmers on production practices and quality management

Processing industry

Characteristics and preferences

- Few companies who might have different scale.
- In the model the existence of the processing industry should be representative for the pilot region. If processing industry is missing, farmers need to find industry in another region or organize themselves for joint marketing of the products.

Key drivers

- Product differentiation.
- Corporate social responsibility.
- Profit might not be the primary driver for processing industry but losses will not be accepted for longer periods.

Key linkages between agents

- Buy primary or pre-processed products from farmers or their cooperatives.
- May have contractual agreements/partnerships with farmers to regulate quantities, quality and payment schemes.
- Sell products to distributors – retailers, specialised shops, HoReCa.

Retailers

Characteristics and preferences

- Few retail chains who dominate the market.
- Some retail chains may be more open for providing outlet for (regional) underutilized crops and products based on these.

Key drivers

- Profit seeking.
- Product differentiation.
- Corporate social responsibility.

Key linkages

- Buy products from farmers and processing industry.

- May have contractual agreements with farmers to regulate quantity, quality and pricing of products.

Short supply chains

Characteristics and preferences

- Different possible outlets – farm shops (also online), farmers' markets, specialised shops (e.g. bakeries).

Key drivers

- Profit seeking – cut out the middlemen.
- Demand in market niches.
- Support from policy instruments for development of short supply chains.

Key linkages between agents

- Direct contacts or agreements with farmers and small-scale food processors to buy products.
- Sell products to individual consumers or HoReCa.

HoReCa

Characteristics and preferences

- Numerous differentiated businesses.

Key drivers

- Profit seeking.
- Product differentiation.
- Demand in market niches.

Key linkages between agents

- Buy products from processors, markets or wholesalers (retailers).
- Direct contacts or agreements with farmers and small-scale food processors.

Consumers

Characteristics and preferences

- Numerous agents – mostly individual consumers but also institutional catering.
- Most buy conventional items from retailers.
- Consumers with specific interests buy from short supply chains, retailers, HoReCa.
- Most prefer habitual tastes, few prefer new tastes.

Key drivers

- Utility maximisation – not only monetary.
- Consumer trends and marketing.
- Social norms and cultural traditions – may also work against some products.
- Awareness raising.

Key linkages between agents

- Buy products from retailers, short supply chains and HoReCa.

For the development of BioValue agent-based model, several tools need to be combined. Repast Platform might be the best option. However, it seems more simpler than the other options which may be drawback depending on the development methodology and the complexity of the model to be created. Points to have in mind:

- Integration with GUROBI or another solver that may be used (if any). In this sense, if the tool can be integrated with python (such as Repast) there should not be any problem. In this case, in principle, if the same methodology as in AGRICORE model is followed, the financial optimisation of the agents should be computed with GUROBI.
- Programming language of the tool and its learning curve for the team of developers.

- Complexity of the interaction between the agents along the supply chain.
  - If the simulation will be "sequential" (i.e. farmer → food processors → food retailers → …) the interaction between agents will be limited, hence a simpler tool will serve.
  - If each agent can interact with any agent from the supply chain, there might be needed a more complex tool.
    - Geographical limitation, if any geographical limitations are imposed, it will restrict the problem and the second option of interactions between action will be more suitable. Moreover, a geographical limitation for the interaction will be more realistic too.
- Constraints:
  - bottlenecks (such as number of threads, number of agents in the value chain, non-customizable attributes of the agents);
  - software (preferable cross-platform and integrated with open-source programming languages);
  - hardware (such as computational cost, necessary resources, etc.).

3. Conclusion

Tasks 2.1, 2.2 and 2.3 of the BioValue project provided valuable reviews that can be used as a foundation for the project and for building the BioValue agent-based model. From the various approaches, functional value chain analysis is the most appropriate for value chain development as well as value chain model creation. FAO (2014) sustainable food value chain framework provides a general environmental and institutional building blocks that could be kept in mind in the model development. Also, in specific to underutilized crops, literature reviews conducted in task 2.1 and task 2.3 brought out numerous specificities, many of which are relevant also for the development and its agents. It is advisable that BioValue tool includes explicitly input segment that focuses on production and distribution of seeds for underutilized crops. Also, interactions with natural environment and organizations that may have a role in value chain development should be considered. Another aspect to consider is to enable flexibility for flows of products, money and information. The characteristics and preferences, key drivers and key linkages were outlined for each of the supply chain segment agents. In general, in each of the segment, there is a need for several agents, some of which may have similar properties but some of which should be different. This creates a complex matrix of agents, which represents the situation in pilot regions but still is a simplification that could be modelled. For the technical model building, it is advisable to start from more simpler value chain representations and interactions between agents, however, if it foreseen that step-by-step, more complex setup is achieved, it might be advisable to select more complex and comprehensive technical tools from the start on.

4. References

BIOVALUE – D2.1 (2022). Deliverable 2.1 – Reviewing of Agro-Food Value Chain Tools.
BIOVALUE – D2.2 (2022). Deliverable 2.2 – Reviewing of agent-based modelling tools.
BIOVALUE – D2.3 (2022). Deliverable 2.3 – Biodiversity in the value chain review.
European Commission, (2018). Value Chain Analysis for Development (VCA4D, Methodological Brief. Frame and Tools, key features of experts' work. Version 1.2. Retrived from https://europe.eu/capacity4dev/value-chain-analysis-for-development-vca4d- documents/ methodological-brief-v12 (Accessed on 25th of March 2022).
FAO. 2014. Developing sustainable food value chains – Guiding principles. Rome. https://www.fao.org/sustainable-food-value-chains/library/details/en/c/265156/