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From Agrobiodiversity to Social-Ecological Transformation:

Defining Central Concepts for the RightSeeds Project

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List of Abbreviations

CBD	Convention on Biological Diversity
CESCR	International Covenant on Economic, Social and Cultural Rights
CSO	Civil Society Organization
CSS	European Campaign for Seed-Sovereignty
DUS	Distinctiveness, Uniformity and Stability
ESS	Ecosystem Services
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
ICNCP	International Code of Nomenclature for Cultivated Plant
IPC	International Planning Committee for Food Sovereignty
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
MEA	Millennium Ecosystem Assessment
NGO	Non-Governmental Organization
SaatG	Saatgutverkehrsgesetz
TEEB	The Economics of Ecosystems and Biodiversity
SER	Social-Ecological Resilience
SVC	Seed and Variety Commons
UDHR	Universal Declaration of Human Rights
UN	United Nations
UPOV	International Union for the Protection of New Varieties of Plants
WFC	World Food Council
WFP	World Food Programme
WTO	World Trade Organization

1 Introduction

The project 'Right Seeds - Commons-based rights on seeds and seed varieties as a driver for a social-ecological transformation of plant cultivation' (RightSeeds) investigates Commons-based approaches to variety breeding, seed production and seed usage. A Commons-orientation in the seed sector, as long practiced in the Global South, provides a promising approach in reorienting the agricultural sector towards the international sustainability goals of food sovereignty and agrobiodiversity. The aim of the RightSeeds project is thus to investigate the potential of Commons-based seed systems to drive a social-ecological transformation of plant cultivation. To achieve this, the project employs a transdisciplinary research approach by integrating perspectives from the fields of ecology, economics, political science and philosophy, and collaborates with German and Philippine seed initiatives, companies and NGOs.

Successfully bringing together different academic disciplines and non-academic actors to address social-ecological issues is a challenging endeavor, which requires knowledge integration at various levels. To engage in a transdisciplinary process of joint analysis and theory building, it is necessary to develop a shared understanding of central terms and concepts in the first phase of the research process (Jahn, 2008; Lang et al., 2012). This is essential to ensure that all researchers and practical partners involved have a common understanding of the research subject and relevant concepts. The aim of this working paper is thus to discuss and define terms and concepts that are central for the RightSeeds project. A main goal is the development of a joint understanding of a Commons-orientation in the seed sector. The paper thus contributes to discussions on the conceptualizations of Commons and is of high relevance for researchers that have an interest in Commons research. It also outlines the historical development as well as the strengths and weaknesses of numerous key terms and concepts (see below). It may consequently be of interest to researchers in the larger field of environmental governance and to early-career researchers aiming to gain an overview of the conceptual development of these terms and concepts.

The paper has the following structure. Firstly, the relevance of developing joint definitions in transdisciplinary research contexts, in general and specifically for the RightSeeds project is highlighted and the integration process outlined. Subsequently key terms and concepts for RightSeeds are defined and, where appropriate, their historical disciplinary developments are retraced. These include (1) seeds, (2) varieties, (3) organic breeding, (4) agrobiodiversity & ecosystem services, (5) food sovereignty, (6) social-ecological transformation and (7) Commons. Finally, a conceptualization of Seed and Variety Commons (SVC) as the common research subject of RightSeeds is proposed and the main relations between the discussed terms and concepts are summarized.

2 Transdisciplinary Epistemic and Communicative Integration

Transdisciplinary research allows for the in-depth exploration of social-ecological issues that due to their complexity cannot be solved by one discipline alone. The RightSeeds research approach builds upon national and international discourses on transdisciplinary sustainability research, which have developed over the past decades (Jahn, 2008; Lang et al., 2012; Mauser et al., 2013). Transdisciplinarity is here understood as a problem- and solution-oriented endeavor, in which new knowledge is generated through the collaboration of scientists from different disciplines and practitioners (e.g. from the fields of civil society, business and politics) (Lang et al., 2012). The RightSeeds transdisciplinary research process interlinks a path of scientific innovation, which aims at generating scientific knowledge, and a path of problem solution, which aims at developing solution strategies for societal issues (Becker & Jahn, 2006; Jahn, 2008; Lang et al., 2012).

A central challenge in transdisciplinary research lies in bringing together a diverse range of expertise and knowledge types in a coherent manner to allow for a consistent research process (Bergmann et al., 2010). To address this, a shared understanding of the subject matter is indispensable. The aim must be to achieve a twofold integration: An interdisciplinary integration of the various disciplinary bodies of knowledge, on the one hand, and a transdisciplinary integration between practical and scientific knowledge types, on the other hand. Both types of integration must occur on an epistemic (developing a common understanding) and a communicative level (developing a common language) (Jahn, 2008).

Interdisciplinary integration requires identifying and highlighting differences among disciplines with respect to epistemic assumptions, schools of thought and scientific methodologies (Jahn, 2008). Specific terminologies are an essential part of disciplinary socialization and are not necessarily self-evident to outsiders. Consequently, it is essential to make explicit what disciplinary discourses take as given and make it comprehensible to researchers from other fields of study. Building upon this, concepts need to be discussed from different academic perspectives in order to delineate disciplinary boundaries. This can lead to increasing conceptual overlaps among different disciplines, while the concepts still show the birthmarks of distinct disciplinary styles of reasoning (Hirsch Hadorn et al., 2008). Furthermore, specific terms often come with the heavy baggage of complex theoretical backgrounds or on-going disputes within a discipline (Fish et al., 2016). This also holds true in transdisciplinary research contexts. Even in monodisciplinary contexts, research needs to position its propositions within the existing array of definitions, as terminologies can be tied to divergent conceptual understandings (Bergmann et al., 2010; Hirsch Hadorn et al., 2008). Diverging understandings may be conflicting. In these cases, it is important to ensure equal participation of the different disciplines to prevent an (implicitly) authoritative interpretation at the expense of integration (Bergmann et al., 2010).

In addition to the integration of various disciplines, the knowledge, views and skills of non-academic stakeholders need to be incorporated. Various action-based tools and methods can be employed for integrative purposes (Christinck & Padmanabhan, 2013). Diversity of stakeholders in research cooperation brings about challenges in equal participation. In the context of historical power disparity between different types of knowledge, awareness of who is granted interpretive authority in the process of conceptual integration is crucial. Western science has and continues to dismiss systematically certain types of knowledge such as traditional or local knowledge (Christinck & Padmanabhan, 2013).

Working out coherent common definitions for a specific research project by means of deliberation allows for the development of a coherent joint terminology that can provide clarity about the issues at stake and a well-grounded starting point for the research process. In the formulation of any definition there are trade-offs between analytical precision and general clarity. Striking a good balance between these aspects is especially crucial in transdisciplinary contexts (Bergmann et al., 2010). For scientific purposes, a clear-cut definition is highly desirable and an indicator for high academic standards. However, in applied contexts, a stringent and abstract definition can limit the scope of application and estrange targeted audiences. Consequently, both analytical and communicate dimensions have to be considered, in the quest of developing a joint language through collaborative processes (Bergmann et al., 2010).

For the RightSeeds project, the research team identified relevant core terms and concepts in the area of interest (as listed above) in a first step. In a second step we examined these terms and concepts against the background of their historical development and their use in different scientific disciplines and political discourses. The terms 'varieties', 'organic breeding' and 'Commons' were discussed with all practical partners at a moderated workshop. We chose these terms due to their high relevance for practical partners and the high degree of controversy of their meaning. In a third step, the integrative theoretical framework of 'Seed and Varieties Commons' (SVC) was developed conjointly with all practical partners. Based on a proposal by the scientific project team, the concept was discussed, refined and adapted according to suggestions by the involved stakeholders. The remaining paper outlines the results of this process.

3 Key Terms and Concepts for RightSeeds

3.1 Seeds

According to the Dictionary of Biology, seeds entail seed and fruit that serve as the regenerative organs of a certain species or variety (Freudig, 2006). A number of EU and national regulations govern the production, processing and trade with seeds. As the research focus of RightSeeds is on vegetable seed, the directive 2002/55/EC of 13 June 2002 on the marketing of vegetable seed and its implementation in German law, the Saatgutverkehrsgesetz (SaatG), has specific relevance. According to these legal frameworks, seeds are seed, seed stock and plant propagation material such as plant parts meant for the production of vegetables. The legal definition of seeds is therefore broader than the biological definition, since it also encompasses seed stocks for plants that propagate through plant cuttings instead of seed (e.g. asparagus). There are three main categories of seeds with different quality requirements regarding their approval and authorization: 'Basic seeds' are seed which have been "produced under the responsibility of the breeder according to accepted practices for the maintenance of the variety" (Art. 2 I lit. c EU Vegetable Seed Guideline). The requirements for basic seeds are the highest. 'Certified seeds' are produced from basic seed or generations prior to basic seed and are intended for the production of vegetables. Such seeds are certified in official examinations (Art. 2 I lit. d EU Vegetable Seed Guideline). 'Standard seeds' are the seeds of a registered vegetable variety and are primarily intended for vegetable production (Art. 2 I lit. e EU Vegetable Seed Guideline). Standard seeds also have to fulfil requirements concerning purity and quality, but do not require certification.

Seeds in the context of the *RightSeeds* project
Seeds are seed, seed stock and plant propagation material such as plant parts that are meant for the production of vegetables (see SaatG, art. 1).

3.2 Varieties

According to the Dictionary of Biology, a variety is a population of cultivated plants that can be clearly distinguished from other populations of the same species based on morphological, physiological, cytological, biochemical and other features (Freudig, 2006). These characteristics must persist after generative or vegetal propagation and be homogenous within the population. The dictionary also refers to the term 'old landraces' with regard to varieties. It recognizes that old landraces tend to be well adapted to local conditions and often contain a wider genetic variability compared to modern varieties. This wider variability can appear in diverse cultivation environments. Landraces are often objects of genetic and cultural research and popular among smallholder farmers since they are better adapted to diverse and marginal cultivation environments. Landrace preservation and use is therefore considered as important to face genetic erosion (Olson et al., 2012).

3.2.1 Varieties in EU and International Legislation

The understanding of varieties has implications beyond mere conceptual discussions in the academic context. In UPOV member states and the EU, new varieties must be included in the Register of Plant Varieties before they can be used commercially. How varieties are defined, especially in regulations on the national, EU or international level, has consequently a direct impact on which new breeds can be registered as a variety and therefore are allowed to be distributed commercially. In Art. 1 UPOV, a variety is defined as a "plant grouping within a single botanical taxon of the lowest known rang" (UPOV Art. 1 lit. vi). A new variety must be clearly identifiable by morphological or physiological characteristics, be distinguishable by one or more important characteristics from any other variety, must be sufficiently homogenous and must remain stable in its essential characteristics after repeated reproduction or propagation (UPOV, Art. 6). In the same way, the EU Vegetable Seed Guideline prescribes that new varieties must be distinct, sufficiently uniform and stable (DUS-criteria) (Art. 4 I). Article 5 further specifies these three conditions:

> *"1. A variety shall be regarded as distinct if, (…) it is clearly distinguishable in one or more important characteristics from any other variety known in the Community. The characteristics must be capable of precise recognition and of precise definition. (…). 2. The variety shall be regarded as stable if, after successive propagation or multiplications or at the end of each cycle (where the breeder has defined a particular cycle of propagation or multiplications) it remains true to the description of its essential characteristics. 3. A variety shall be regarded as sufficiently uniform if, apart from a very few aberrations, the plants of which it is composed are, account being taken of the distinctive features of the reproductive systems of the plants, similar or genetically identical as regards the characteristics, taken as a whole, which are considered for this purpose". (EU Vegetable Seed Guideline, Art. 5).*

Seed and variety registration laws emerged with the rise of commercial plant breeding and the modernization of agriculture that required more uniform varieties (Chable et al., 2014). Before, seeds of different varieties were often sold under the same name. Variety registration was introduced to create transparency on the market and provide an independent source of agronomic information for farmers. Variety testing became increasingly specialized and the first official catalogs of recommended varieties were published in the 1920s in Europe. A greater uniformity in varieties became important with the mechanization of agriculture from the 1930s. The Distinctiveness, Uniformity and Stability (DUS) norms were developed in the 1940s to clearly identify a variety (Chable et al., 2014).

With the emergence of new breeding techniques, a new form of varieties emerged. F1-Hybrids are the result of crossing two purebred lines. Hence, they are plants of a line that result from the repeated self-fertilization or inbreeding for specific traits (Freudig, 2006). The fertility of these purebred lines is significantly reduced. When two such purebred lines are crossed, the resulting daughter generation (F1-generation) possesses the desired qualities and is often highly productive. This is called the heterosis-effect. The heterozygous F1-generation is more vital than its parental generation. However, this effect only persists for one generation. A successful reproduction of descendants with the same characteristics is not possible (Freudig, 2006).

3.2.2 Challenges of the DUS Criteria

The strict DUS criteria are often considered as problematic for organic breeding and with regard to farmers' rights (Christinck & Tvedt, 2015). Especially the uniformity criterion presents difficulties since it prevents varieties from being genetically diverse (Serpolay et al., 2011). For low input farming (no application of pesticides and mineral fertilizers), a broad selection of genetically diverse varieties is needed for independent variety choice under diverse environmental conditions and breeding possibilities towards the development of resistance to pests and diseases. A narrow genetic basis in turn can restrict varieties' ability to adapt to changing environmental and climate conditions. In reality, modern plant breeding is geared towards creating uniform varieties for standardized high-input farming systems. Consequently, the majority of registered varieties is genetically homogenous and many of them have the same parental varieties. This endangers the diversity of genetic material (Serpolay et al., 2011). Hence, a strict application of the uniformity standard can threaten agrobiodiversity by lowering for example food sources for pollinators due to equal flowering periods of (in monoculture) cultivated varieties. More diversity in varieties and/or populations may contribute to human food security by more diverse cultivation periods and better adaptation to changing environmental and climate conditions (Christinck & Tvedt, 2015). While the DUS criteria are adapted to the demands of a standardized industrial agriculture, especially small-scale farmers in the Global South have different needs. For such farms, a reliability of yields over time is more important than particularly high yields that only occur under ideal conditions. A similar performance with regard to diverse locations (spatial homogeneity) is less important for those small-scale farmers (Christinck & Tvedt, 2015; Kotschi, 2010, 2010; Serpolay et al., 2011).

3.2.3 Other Types of Varieties

Besides the official, legal definitions of varieties based on the DUS criteria, a wide range of terms in the context of varieties is being used in the literature, often heterogeneously or even contradictory (Serpolay et al., 2011). Common terms are landraces, farmer varieties, historic varieties, modern varieties, cultivars, conservation varieties and varietal mixtures.

Besides 'varieties', the term 'cultivar' is occasionally used. The International Code of Nomenclature for Cultivated Plants (ICNCP)[1] provides an internationally recognized system for naming plants in cultivation. This regulation applies to "all organisms traditionally treated as plants (…) whose origin or selection is primarily due to intentional human activity" (ICNCP, Pre. 7). Varieties always result from human influence, but the term 'cultivars' underlines the conscious human contribution to their development (Klaus, n.d.). To be included in the ICNCP, a cultivar must be "an assemblage of plants that (a) has been selected for a particular character or nomination of characters, (b) is distinct, uniform,

[1] Brickell, 2009, in the following referred to as ICNCP

and stable in these characters, and (c) when propagated by appropriate means, retains those characters" (ICNCP, Art. 2.3).

Serpolay et al. (2011) describe farmer varieties as an umbrella term for varieties that were developed and managed by farmers, including landraces, historic varieties and variety mixtures. Landraces encompass a broad range of different aspects. Camacho Villa et al. (2005) define them as follows:

> *"A landrace is a dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems". (p. 381).*

As this comprehensive description suggests, a combination of these six criteria can constitute a landrace, while no single criterion is considered the most important or an essential one. Most varieties that are generally considered as landraces would be excluded by at least one of these criteria. Depending on the specific crop and frame conditions there can be different priorities, e.g. some might rather underline a great genetic diversity, while in other cases a good adaptation to local conditions is the most relevant factor (Kotschi, 2010). Farmers often cultivate different varieties and crops together in a varietal mixture, thereby encouraging genetic drift and the development of quite diverse populations[2] (Christinck & Tvedt, 2015). This often high genetic diversity of landraces is their greatest strength but also poses a huge challenge as it does not allow for a clear description of their identity. Nevertheless, identification is important and landraces need to be recognizable as a distinct entity with common shared traits. This raises the question which traits are needed to define a landrace (Christinck & Tvedt, 2015).

Historic varieties are relatively homogenous selections from a landrace or varieties from early stages of formal plant breeding programs. Until 1950, they were typically registered in the official catalogue (Serpolay et al., 2011, p. 128). Modern varieties typically result from formal plant breeding programs and are registered in variety catalogues. Hence, they fulfill the above-mentioned criteria of uniformity, stability and distinctiveness (Serpolay et al., 2011). Conservation variety is a legal term that the EU introduced to contribute to the conservation of genetic variety. This type of variety is discussed below.

3.2.4 Conservation Attempts and Conservation Varieties

Landraces have a substantial historical value and significance, since they are the foundation for all seeds used today: Their diversity is often used for developing new varieties and particularly such that are well adapted to difficult circumstances or resistant to diseases or pests and nutritional quality. Moreover, they still play an important role in agriculture today with regard to yield stability, especially in marginal environments and traditional and subsistence farming systems. However, landraces suffer a threat of being replaced by modern varieties, which has already caused a widespread genetic erosion (Kotschi, 2010).

[2] A population is a group of individuals of the same or different genotypes, which originate from a common genepool and reproduce sexually (Odenbach & Diepenbrock, 1997).

The need to preserve plant genetic resources for the developments of new resilient breeding is widely recognized. For example, both the conservation and sustainable use of seeds and varieties on-farm (in-situ) and externally (ex-situ) in gene or seed banks have been identified as central objectives in the Convention on Biological Diversity (CBD). Ex-situ conservation has become popular both by private and public institutions (Thrupp, 1998). The intention is to maintain the characteristics of the varieties as they are. This is problematic, though, since it does not allow for a continued evolution of varieties whereby they naturally adapt e.g. to changing environmental conditions. Moreover, while in theory seeds stored in such banks should be available to everyone, access is often difficult to obtain especially for local communities in the Global South (Thrupp, 1998). In contrast, in-situ conservation means that the diversity is maintained by local adaptation and selection directly on the farms. This enables an ongoing evolution process. In-situ conservation also "conserves the processes that create and maintain the genetic diversity of populations, rather than a particular sample of genetic diversity" (Serpolay et al., 2011, p. 129).

The EU has recognized the importance of in-situ conservation. Since landraces mostly do not meet the criteria for uniformity, an exceptional rule for so-called 'Conservation Varieties' has been added to EU legislation to classify old varieties and allow their production, sale and exchange. According to the EU Commission Directive 2008/62/EC (2008) (the Conservation Variety Directive), conservation varieties must be linked to a region of origin, where they have been cultivated for a certain period. They are threatened by genetic erosion, and "present an interest for the conservation of plant genetic resources" (Conservation Variety Directive, Art. 4 I). For those varieties, less strict DUS criteria apply (e.g. a tolerance of 10% off-types with regard to the uniformity standard instead of 1%) (Art. 4). There are some major restrictions, though. Conservation varieties may only be produced in their region of origin and their quantity is limited to a maximum of 100ha or 0.5% of the quantity of seeds of the same species in the member state in one growing season.

Glossary of Variety Types

Cultivar: "Deliberately selected plants that may have arisen by intentional or accidental hybridization in cultivation, by selection from existing cultivated stocks, or from variants within wild populations that are maintained as recognizable entities solely by continued propagation" (ICNCP, Pre. 1, fn. 1).

Modern Variety: A variety resulting from a formal plant breeding program, registered under a distinct name and satisfying the criteria of distinctiveness, uniformity and stability as defined by regulations of the variety registration process (Serpolay et al., 2011, p. 128).

Hybrids: Hybrids are the result of crossing two purebred lines. They are hence plants of a line that result from the repeated self-fertilization or inbreeding for specific traits. They are highly productive and homogenous in the F1 generation, but these characteristics are not reproducible (Freudig, 2006).

Farmer Varieties: These varieties were historically developed and managed by farmers. They can include landraces, historic varieties and variety mixtures (Serpolay et al., 2011, p. 128).

Landrace: Landrace refers to "a dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems" (Camacho Villa et al. 2005, p. 381).

Historic Varieties: Historic varieties are relatively homogenous selections from a landrace or varieties from early stages of formal plant breeding programs. Until 1950, they were typically registered in the official catalogue (Serpolay et al., 2011, p. 128).

Conservation varieties: This is a legal term introduced by EU Directive. Conservation varieties are linked to a region of origin, where they have been cultivated for a certain period. They are threatened by genetic erosion, and "present an interest for the conservation of plant genetic resources" (Conservation Variety Directive, Art. 4 I).

Varietal mixture: "A mixture of distinct plant types, that are grown and harvested together. Components of the mixture can be landraces, historic varieties or modern varieties" (Serpolay et al., 2011, p. 128).

Population: A group of individuals of the same or different genotypes, which originate from a common genepool and reproduce sexually (Odenbach & Diepenbrock, 1997).

3.2.5 Relevance for Commons: In Need of a New Understanding of Varieties?

For the project RightSeeds, a comprehensive understanding of varieties is needed that encompasses both farmer varieties and modern varieties. Aspects of Commons play a role both in the breeding and marketing of new varieties in the formal seed sector (e.g. by our practical partners Kultursaat e.V., Saatgut e.V., Bingenheimer Saatgut AG); and with regard to the conservation, exchange and further development of farmer varieties in more informal seed systems especially in the Global South (e.g. in the work of MASIPAG, Arche Noah e.V., Dreschflegel or the initiative RegioSaatgutCoop).

The most broadly used definition of varieties is the legal one that refers to the registration of new varieties and is based on the criteria of distinctiveness, uniformity and stability. However, as shown above, while this definition can be useful to distinguish modern varieties in a formal seed system, it is not adapted to the needs of more informal breeding structures. These criteria are interpreted quite narrowly and can make it difficult even for new breeds to be accepted as varieties. Therefore, the context of RightSeeds requires a more comprehensive understanding of varieties.

Possibilities for a useful working definition of varieties were discussed in the transdisciplinary workshop that initiated the common work of the scientific team and the practical partners in the RightSeeds project. The discussion highlighted diverging perspectives on the understanding of varieties. However, there was consensus that while the DUS criteria are useful for accurate descriptions and a high degree of identifiability of varieties, the narrow interpretation of the DUS criteria is problematic. The most prominent argument was that varieties need sufficient variability to adapt to changing environmental and climate conditions. From this perspective, the time span considered regarding the criteria of stability becomes a decisive factor. Based on these considerations, we propose the following working definition of varieties for the use in the project RightSeeds.

Varieties in the context of the *RightSeeds* project

A variety is a population of cultivated plants that can be clearly identified and distinguished as a distinct entity with a number of common shared traits (morphological, physiological, cytological, biochemical and other features) from other forms within a species. These key characteristics must remain stable after successive generative, vegetal propagation or reproduction. A variety must be sufficiently homogenous. Therefore, the plants of which it is composed of are, apart from a small percentage of aberrations, similar or genetically identical with regard to is defining characteristics. Nevertheless, a variety can encompass a certain variability and genetic diversity among its individuals with regard to less distinctive features in order to adapt to changing (environmental and climate) conditions (based on UPOV, Art. 6; EU Vegetable Seed Guideline, Art. 5; Freudig, 2006).

3.3 Organic Breeding

Many of the above discussed challenges are linked to breeding approaches. The demands towards a new variety impact how breeding is pursued and vice versa. Most of the practical partners of the RightSeeds project who include aspects of Commons in their work are active in the field of organic breeding. Despite the close linkage of Commons orientation and organic breeding, especially in the German-speaking context, from a conceptual standpoint the two concepts are not necessarily interlinked. In the following, a clarification of the concept of organic breeding is given.

Organic breeding has developed as an alternative breeding approach to the increasingly technical methods in conventional and industrialized breeding, especially in response to emerging methods in the field of biogenetics. Since the 1990s, discussions on developing breeding methods specifically for the organic sector have intensified (Nikisch, 2007). There are two main reasons for the emergence of these discussions. Firstly, organic farming has different needs regarding the characteristics of newly-bred varieties than conventional farming due to its low-input agriculture. Secondly, some methods employed in conventional breeding stand in contrast to the holistic principles of organic farming.

From a legal perspective, organic farming does not necessarily require the use of varieties from organic breeding programs, but instead only the use of organically produced seed and propagating material according to the European Organic Regulation 834/2007. This means that the mother plant in the case of seeds and the parent plant in the case of vegetative propagating material need to be produced in accordance with the rules laid out in this regulation for at least one generation, or, in the case of perennial crops, two growing seasons (Art. 12 lit. i, European Organic Regulation). Varieties that were bred for the conventional agricultural sector can still be used in organic farming, and consequently, more than 95% of organic agriculture is still based on these varieties (Lammerts van Bueren et al., 2011).

When varieties from conventional breeding are used for organic farming, seeds are propagated under organic conditions as specified in the European Organic Regulation. The breeding itself is oriented towards the needs of the conventional and industrialized agriculture. Consequently, the diverging performance in conventional and organic systems is not considered. In particular, resistances against weeds, pests and diseases are not sufficiently developed due to (extensive) inputs of pesticides, fungicides and herbicides in conventional agriculture (Messmer, 2014). Moreover, in organic farming, there is a stronger dependence on the conditions of the location at which varieties are cultivated since the use of mineral fertilizers is renounced (Horneburg, 2016). Varieties for organic farming need to be productive also in face of a limited availability of nutrients. Overall, a broader range of varieties is needed to better adapt to diverging conditions. However, adapted and high-performing species are often not available. This limits the diversity of organic farming. Consequently, own breeding programs for organic farming are necessary (Horneburg, 2016). Breeding for organic farming (Messmer, 2014) aims at producing varieties that are adapted to the needs in organic farming. Selection takes place under organic farming conditions and methods of bioengineering or cell fusion are not employed. Varieties are tested and propagated under organic conditions.

In addition to such breeding programs for organic farming, a further type of breeding, organic breeding, has developed that includes an additional process-oriented dimension. Here, the principles of organic farming are transferred to organic breeding and a holistic perspective is pursued (Lammerts van Bueren, 2010). All steps of the breeding processes, selection and propagation take place under organic conditions and are adapted to the specific requirements in organic farming. The procedures of breeding and agriculture are considered rather than the mere product and the employed techniques are consistent with the values of organic agriculture (Nikisch, 2007). While there is no legal definition of organic breeding, a range of private-law binding definitions and position papers, especially of organic associations, exist. The International Foundation for Organic Agriculture (IFOAM) has elaborated a comprehensive definition of organic breeding that is widely accepted and upon which the practical and scientific partners of RightSeeds agreed at the first project workshop. The ethical foundation for organic farming and hence for this definition lies in the respect of the integrity and dignity of plants and recognizes their intrinsic value, which reflects in the principles of health, ecology, fairness and care (Lammerts van Bueren, 2010). Concerning plant breeding and seed production the principle of health means that varieties should be bred to be resilient and robust against pests and diseases or weeds and should not be limited in their capacity to reproduce. The principle of ecology embeds the plant in its ecological system, which means that breeding should be directed towards regional adaptability and should foster a high genetic diversity. The principle of fairness aims at justice, respect and equity, including a free access to genetic resources and the prohibition of patents. Finally, the principle of care encompasses that any advancements of the productivity and efficiency in plant breeding should respect the precautionary principle (Lammerts van Bueren, 2010).

Breeding of organic varieties (IFOAM Principles 2014)

Organic plant breeding and variety development is sustainable, enhances genetic diversity and relies on natural reproductive ability. It aims for new varieties particularly suited for organic production systems. Organic breeding is always creative, cooperative and open for science, intuition, and new findings. Organic plant breeding is a holistic approach that respects natural crossing barriers. Organic plant breeding is based on fertile plants that can establish a viable relationship with the living soil. Organic varieties are obtained by an organic plant breeding program.

Requirements:

1. To produce organic varieties, plant breeders shall *select their varieties under organic conditions* that comply with the requirements of this standard. All multiplication practices except meristem culture shall be *under certified organic management.*

2. Organic plant breeders shall develop organic varieties only on the basis of genetic material that *has not been contaminated by products of genetic engineering.*

3. Organic plant breeders shall disclose the applied breeding techniques. Organic plant breeders shall make the information about the methods, *which were used to develop an organic variety, available for the public latest from the beginning of marketing of the seeds*.

4. The *genome is respected as an impartible entity*. Technical interventions into the genome of plants are not allowed (e.g. ionizing radiation; transfer of isolated DNA, RNA, or proteins).

5. *The cell is respected as an impartible entity.* Technical interventions into an isolated cell on an artificial medium are not allowed (e.g. genetic engineering techniques; destruction of cell walls and disintegration of cell nuclei through cytoplast fusion).

6. The *natural reproductive ability of a plant variety is respected and maintained*. This excludes techniques that reduce or inhibit the germination capacities (e.g. terminator technologies).

3.4 Agrobiodiversity and Ecosystem Services

3.4.1 Biodiversity

Biodiversity refers to the variety of plant and animal life and has its origins in political and scientific debates of the 1980s. The term was first coined at the 'National Forum on BioDiversity' in Washington in 1986, whose contributions were collected in a book called 'Biodiversity' (Hammer, 1998). In 1992, the Convention on Biological Diversity was drafted as an outcome of the Rio Earth Summit. Biodiversity also plays a central role in the global ecosystem services debate since both concepts strongly influence each other (see section on 'Ecosystem Services and Agrobiodiversity' below). Biodiversity is thus central in the Millennium Ecosystem Assessment (MEA) framework, the Economics of Ecosystems and Biodiversity (TEEB) process and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Bartkowski et al., 2015).

The concept has strongly evolved since the 1980s and a huge variety of different definitions of biodiversity has emerged. DeLong (1996) gives an overview of the broad range of conceptualizations. These range from definitions that merely focus on the quantity of species to those that incorporate the whole diversity and variability of nature. The International Convention on Biological Diversity (CBD, 1992) provides the most widely used and accepted definition of biodiversity. It defines biodiversity as:

> *"the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". (CBD, 1992, Art. 2 I)*

A central criticism with regard to biodiversity is its broad and unspecific scope, which makes it difficult to operationalize the concept. This is especially so, since the concept has been applied to diverse contexts. Hence, conceptualizations of biodiversity have to be adopted to the specific contexts they are used in. The use of sub-concepts can be helpful (Bartkowski et al., 2015). With the RightSeeds project focusing on seeds and varieties, the sub-concept of agrobiodiversity is highly relevant and is thus further explored below.

3.4.2 Agrobiodiversity

Agrobiodiversity is a subset of biodiversity and agrodiversity. Agrodiversity refers to the variation in cropping systems, output and management practices and their interactions within and between agroecosystems (Brookfield, 2001). Agrobiodiversity entails those dimensions of biodiversity that relate to food and agricultural production and, more broadly, to the aspects of biodiversity that support the functionality of the agro-ecosystem. The concept of agrobiodiversity includes three levels of diversity: (1) the genetic, (2) the species and (3) the ecosystem level. Contrasting to biodiversity, discourses on agrobiodiversity place a strong emphasis on humans and their interactions with agro-ecosystems. Agrobiodiversity is strongly influenced by farming practices, breeding practices and the cultivation of species (Cromwell, 1999; Stadtlander, 2016). Jackson et al. (2007) differentiate between planned and associated agrobiodiversity. 'Planned agrobiodiversity' is the biodiversity of the crops and livestock intended by farmers, while 'associated agrobiodiversity' refers to the surrounding flora and fauna affected by the management and the environmental conditions.

The Scope of Agrobiodiversity

Similar to biodiversity, there are many different definitions of agrobiodiversity with different foci and scopes. Frison et al. (2011) organize their definition according to the three levels of diversity (genetic, species, ecosystem). It recognizes both the aspects of agrobiodiversity, which are directly managed and intended to produce specific goods or services and those aspects that are unintended and that provide supporting functions for the larger agro-ecosystem.

> *"Agricultural biodiversity includes those components of biological diversity relevant to food and agriculture as well as the components of biological diversity that constitute the agro-ecosystem. It exists at several levels, from the different ecosystems in which people*

raise crops and livestock, through the different varieties and breeds of the species, to the genetic variability within each variety or breed. While part of this biodiversity is directly managed to supply the goods and services that people need, much is not directly intended for production but remains important as a source of materials and for its contributions to ecosystem services such as pollination, control of greenhouse gas emissions and soil dynamics" (Frison et al., 2011, p. 239).

Some conceptualizations of agrobiodiversity highlight the social dimension of the concept. Literature frequently identifies especially knowledge about agricultural as an important component. Such knowledge is accumulated through experiences and is therefore linked to cultural diversity, beliefs, customs and practices (Thrupp, 1998). Thrupp includes cultural and local knowledge of diversity in his overview graph of the main components of agrobiodiversity (see fig. 1) and highlights the broader benefits of agrobiodiversity to humans:

"Agrobiodiversity makes it possible for farmers to recycle nutrients, reduce pest and disease problems, control weeds, maintain good soil and water conditions, and handle climatic stress, while producing agricultural products necessary for health and human survival. It therefore has multiple economic, ecological, and social benefits" (Thrupp, 1998, p. 5).

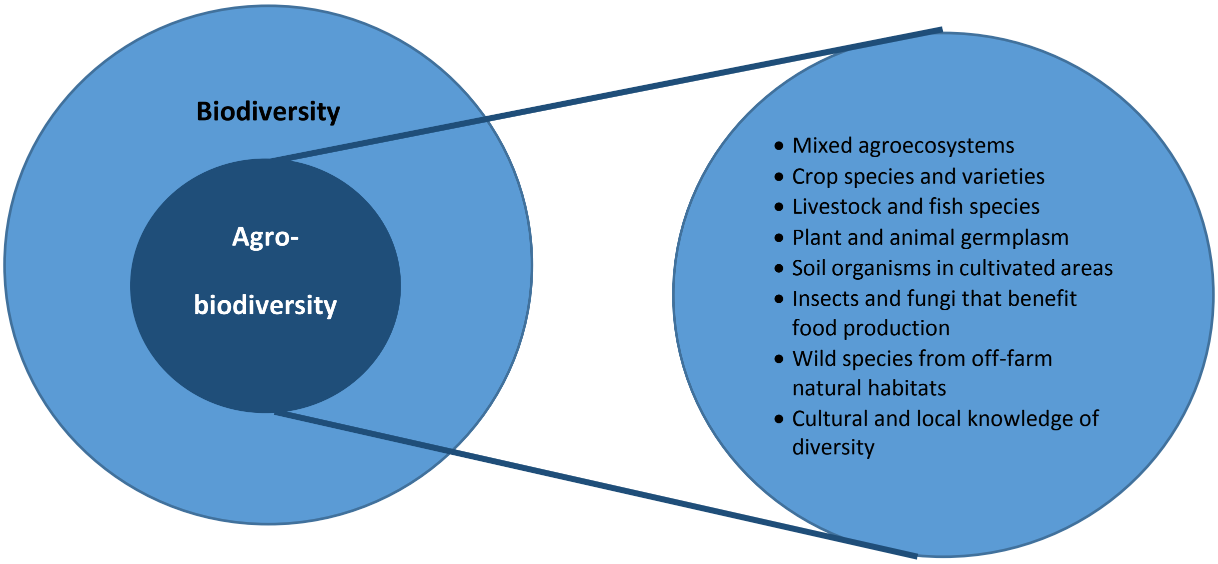

Figure 1: *Conceptual view of Agrobiodiversity (own figure, following Thrupp 1998, p. 11, fig.2)*

Similarly, Cromwell (1999) links agrobiodiversity to food security and food sovereignty and emphasizes the decisive role of humans and their culture and knowledge in the conservation of agrobiodiversity. Some approaches to agrobiodiversity also include the management of biological resources and the diversity of organizational models (Thrupp, 1998). The comprehensive definition provided by the FAO (1999) includes the diversity of management and culture[3]:

> *"Agricultural biodiversity refers to the variety and variability of animals, plants, and micro-organisms on earth that are important to food and agriculture which result from the interaction between the environment, genetic resources and the management systems and practices used by people. It takes into account not only genetic, species and agro-ecosystem diversity and the different ways land and water resources are used for production, but also cultural diversity, which influences human interactions at all levels. It has spatial, temporal and scale dimensions. It comprises the diversity of genetic resources (varieties, breeds, etc.) and species used directly or indirectly for food and agriculture (including (…) crops, livestock, forestry and fisheries) for the production of food, fodder, fibre, fuel and pharmaceuticals, the diversity of species that support production (soil biota, pollinators, predators, etc.) and those in the wider environment that support agro ecosystems (agricultural, pastoral, forest and aquatic), as well as the diversity of the agro-ecosystems themselves" (FAO, 1999, p. 5).*

This broad understanding of agrobiodiversity is not commonly accepted. (Brookfield, 2001) for instance sees agrobiodiversity as one of three subsets of agrodiversity. He defines agrodiversity as:

> *"the dynamic variation in cropping systems, output and management practice that occurs within and between agroecosystems. It arises from bio-physical differences, and from the many and changing ways in which farmers manage diverse genetic resources and natural variability, and organize their management in dynamic social and economic contexts" (Brookfield, 2001, p. 46).*

According to Brookfield (2001), agrodiversity is more encompassing than agrobiodiversity, since it also includes the three elements of biophysical diversity, management diversity and organizational diversity. Hence, the concept of agrobiodiversity, in his understanding, refers mainly to the diversity of the ecological aspects of agriculture. While knowledge about agricultural practices is still considered as an aspect of agrobiodiversity, the socio-economic dimension is much more prominent in the concept of agrodiversity. This embedment of agrobiodiversity within agrodiversity helps to clearly confine the scope of the concept of agrobiodiversity and prevents the risk of an all-embracing, yet unmanageable concept.

Agrobiodiversity in the context of the RightSeeds project

In the context of RightSeeds, we recognize the importance of the social dimension for the sustenance and the development of agrobiodiversity as well as the beneficial effects that agrobiodiversity can have for a resilient and just food system (see chapter 3.5.3. on the impact of agrobiodiversity on providing multiple ecosystem services). However, a conceptualization of agrobiodiversity that encompasses also the diversity of management and organizational practices is too broad to provide a useful analytical

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[3] A shorter and slightly different version of a FAO definition of agrobiodiversity is widely (mis)quoted with reference to this background paper on agricultural biodiversity (FAO, 1999). A respective primary source was not traceable; therefore, we refer to this more comprehensive version.

lens. Since the focus of the RightSeeds project is on Commons-based initiatives in the fields of seeds and varieties, the concept of Seed and Variety Commons, which is developed later in this paper (see chapter 4), will serve as more adequate framing for analyzing and evaluating the social and organizational dimensions of agricultural systems.

In the context of seeds and varieties, some aspects of agrobiodiversity are particularly relevant. A high diversity between and within different species is essential for an agricultural system that is adapted to local conditions and to different needs of farmers (Chateil et al., 2013; Frison et al., 2011; Hajjar et al., 2008; Lin, 2011). A high diversity within a variety through different subpopulations can increase the resistance to pests and diseases (Letourneau et al., 2011). A high diversity of genetic material is also an important basis for future plant breeding, which is capable of reacting to climate-imposed challenges (Frison et al., 2011; Lin, 2011). Diversity on these different levels is developed and maintained through the conservation and sustainable management of ecosystems (Hajjar et al., 2008). All of these aspects can increase the overall resilience of agricultural systems in face of changing conditions such as climate change and can contribute to food security and food sovereignty (Allen et al., 2014; Frison et al., 2011). The following chapter assesses the relationship between agrobiodiversity and ecosystem services in more detail. Taking into account the above outlined considerations, we conceptualize agrobiodiversity in the context of the RightSeeds project as follows.

Agrobiodiversity in the context of the *RightSeeds* project

Agrobiodiversity entails the variety and variability of plants, animals and microorganisms at the genetic, species and ecosystem level, which are necessary to sustain key functions in the agro-ecosystem, its structures and processes for, and in support of, food production and food security. Knowledge about agricultural practices and culture are integral parts of agrobiodiversity as they contribute to the conservation of agro-ecosystems. Agrobiodiversity comprises the diversity of and within genetic resources (gene combinations, varieties, breeds, etc.), of species used directly or indirectly for food and agricultural production (crops, livestock, forestry and fisheries) including the production of fodder, fiber, fuel and pharmaceuticals. It also contains the diversity of species that support production (soil biota, pollinators, predators, etc.) and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic), as well as the diversity of agro-ecosystems themselves (own definition, based on Cromwell, 1999, p. 7; FAO, 1999, p. 5).

3.4.3 Ecosystem Services

The concept of ecosystem services (ESS) highlights the numerous benefits humans obtain from ecosystems. Providing an analytical framework that has been applied across scales and ecosystems, the ESS concept has, in recent years, developed into an influential approach in conceptualizing the relationship between nature and society. Popularized through the UN Millennium Ecosystem Assessment (2005), it has served as a vehicle for communication between the spheres of academia and policy-making. In academic contexts, the concept provides the basis for a growing body of literature that measures and (economically) assesses the value(s) humans ascribe to the services that natural ecosystems provide directly or indirectly. In political contexts, interest has grown in using the approach to underpin decision-making processes with scientific analyses and to (economically) assess how ecosystem service loss (or gain) translates into welfare loss (or gain). A shared aim lies in the desire to improve environmental management and policy through a better understanding of the interlinkages between ecosystem functions and processes and human well-being. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) plays a central role in this, as it aims to strengthen the science-policy interface for biodiversity and ecosystem services. Central to the IPBES approach is the integration of various types of disciplinary and local knowledge in the context of the ESS Framework in order to catalyze the formulation of knowledge-based policies (Díaz et al., 2015). In the years to come, it is likely to develop into an influential framework for the ESS literature.

Policy and public discourses have been dominated by a generalized definition of ESS, as first introduced by the Millennium Ecosystem Assessment (2005): "The benefits that people obtain from ecosystems". In academia, more refined terminology and conceptual definitions of ESS have evolved with time and across disciplines (for detailed reviews see Braat & de Groot, 2012; Danley & Widmark, 2016). Although the concept originated in the natural sciences, it is rooted in and shaped by both ecological and economic discourses. As such, modern-day transdisciplinary understandings of ESS bridge natural and social sciences, incorporating methodologies and epistemological assumptions associated with both branches of science. To gain a better understanding of the various conceptions of ESS, it is useful to reflect briefly upon their historical origins.

Historical development of the concept

Ecological scholars examined ecosystem functions as early as the 1950s (e.g. Odum, 1953). However, these studies were limited to ecological processes, such as energy flows and nutrient cycles. The 60s and 70s were characterized by a number of publications from natural scientists that highlighted the usefulness of nature to societies and explicitly recognized the social implications of the presence of certain ecosystem functions. The terminology of these scholars developed from 'functions of nature' (Helliwell, 1967), over 'environmental services' (Wilson & Matthews, 1970), and 'public service functions' of the environment and ecosystems (Ehrlich et al., 1977) to 'ecosystem services' (Ehrlich & Ehrlich, 1981). The continuous focus on the structure of ecosystems and the interactions between physical components continues to influence modern-day natural science understandings of ESS, which frequently highlight the importance of the ecological functions and processes that underlie the creation of social welfare. ESS are seen as the 'conditions and processes' (Daily, 1997), 'the capacity of natural processes and components' (De Groot et al., 2002) or 'a set of ecosystem functions' (Kremen, 2005) that allow to sustain and fulfill human life.

Contrasting, in economic discourses, the focus has been more on the human side of the equation, highlighting the (economic) benefits societies yield from ecosystems. Following the industrial revolution, economic production functions focused on labor as primary source of value creation and initially almost completely disregarded natural resources (Gómez-Baggethun et al., 2010). Neoclassical economics considered natural inputs substitutable by manufactured capital and almost entirely neglected ecosystems' contribution to economic value creation. A wave of modern environmentalism in the 1970s led to increasing efforts to frame environmental issues in economic terms. Consequently, natural processes regained in relevance in economic development planning and decision making processes. Schumacher's (1973) introduction of the concept of natural capital and the emergence of the field of ecological economics in the early 1980s furthered the recognition that environmental systems play a fundamental role in determining countries' economic output and social well-being. Contrasting to neoclassical environmental economists, ecological economists argued for a strong sustainability approach in which natural and manufactured capital are considered complementary, not substitutable (Costanza & Daly, 1992) and therewith paved the way for the ESS approach. The economic valuation of ecosystem services became popular in the 1990s when scholars recognized the potential of monetizing these services for informing decision-making processes. Costanza et al.'s (1997) study on the total global value of ecosystem services, which they estimated at US$ 33 trillion per year provided a milestone in popularizing the concept. Given this focus on value creation, it is no surprise that definitions that emerged out of these discourses have often considered ESS as the 'goods and services' (Jenkins et al., 2010; Nelson et al., 2009), 'the outputs' (Haines-Young & Potschin, 2013), or 'the benefits' (Costanza et al., 1997) that human populations derive from ecosystems. Contrasting to conceptualizations that emerged out of ecological discourses, ESS are not the internal processes of nature that create the possibility of human welfare, but they are by definition the social benefits we obtain from ecosystems (also see Nahlik et al., 2012).

The systematic categorization of ESS has been less controversial. Four types of services are commonly distinguished: (1) Provisioning services (products obtained from ecosystems such as food, water, timber or fuels); (2) Regulating services (which contribute to the regulation of ecosystem processes such as the regulation of diseases, floods, droughts or climates); (3) Cultural Services (non-material services provided by ecosystems such as recreational benefits, or aesthetic or spiritual values); and (4) Supporting services (which allow for the presence of other services such as biomass production or nutrient- and water cycles) (Millennium Ecosystem Assessment, 2005). The figure below illustrates the linkages between these types of services and constituents of well-being.

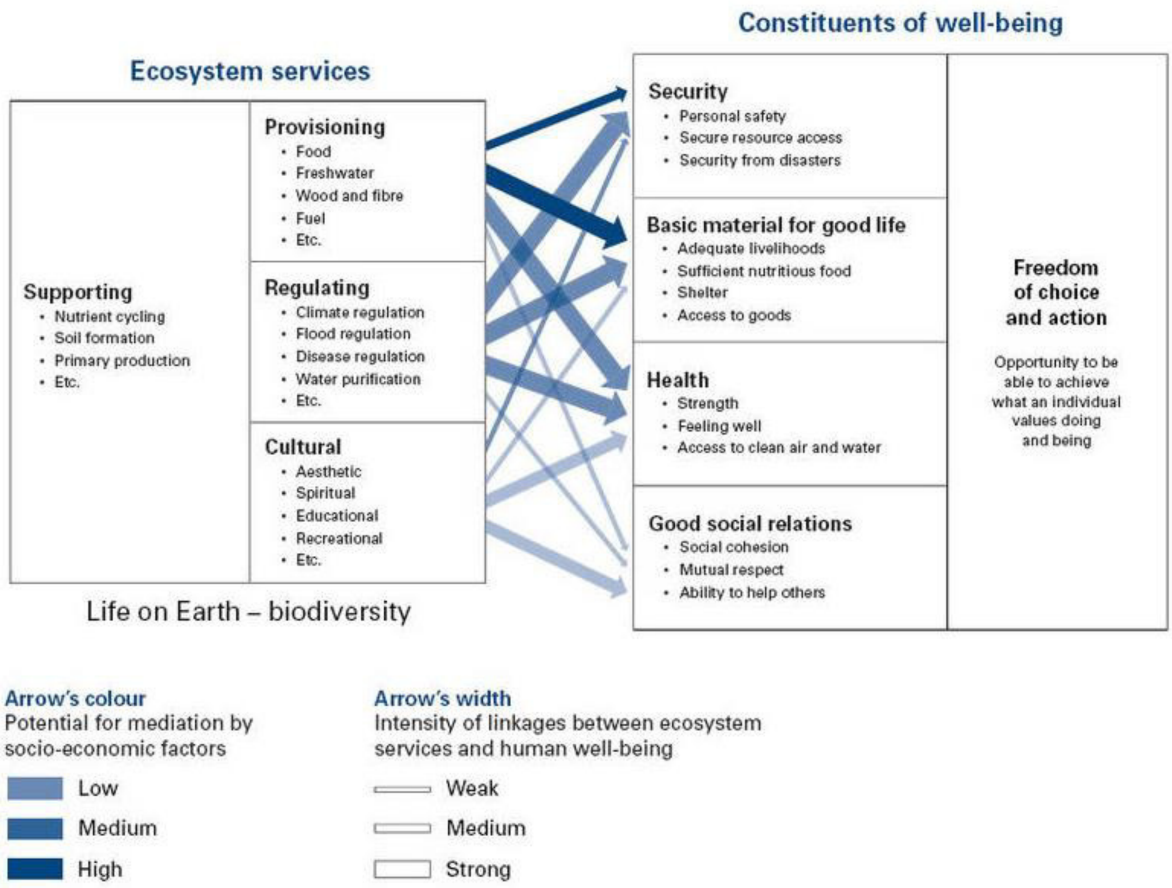

Figure 2: *Displays the relationship between Ecosystem services and well-being (Millennium Ecosystem Assessment, 2005)*

Criticisms

The theoretical underpinnings and real-world applications of the ESS approach have been subject to controversial debates. As compiled by Schröter et al. (2014), criticisms of the ESS approach include: (1) its anthropocentric focus which may promote exploitative human-nature relationships and dismiss nature's intrinsic values; (2) the far reaching commodification of nature and the false assumption that payments for ecosystem services will necessarily ensure their long-term provision; (3) an obliviousness to ecological 'disservices' due to the concepts normative aims of protecting inherently good ecosystems; (4) a lack of consistency in definitions of ESS, resulting in ambiguities in its operationalization; and (5) conflicts with the concept of biodiversity and the danger that the ESS approach may replace conservation goals.

Countering these criticisms, ESS scholars have argued that the anthropocentric focus and the economic lens of ESS can facilitate the reconnection of society to nature by allowing for a new strand of arguments for the protection of ecosystems (Schröter et al., 2014). This may convince opponents of environmentalism of ecosystems' values. ESS scholars have also pointed out that the approach does not necessarily need to involve monetization, but that such assessments can provide useful additional information for decision making processes (Chan et al., 2012). While it is important to acknowledge the normative assumptions that underlie the ESS approach, ultimately, all concepts and frameworks have normative underpinnings. A concept's embeddedness in sociocultural contexts and the presence of normative goals is, per se, no ground for rejection. The ambiguity of the concept, some ESS scholars have argued, is necessary to allow for transdisciplinary approaches and for the interaction of actors that may not have a consensus on the exact meaning of the concept (Schröter et al., 2014).

While the precise relationship between biodiversity and ESS remains ambiguous, a growing body of evidence suggests that biodiversity underpins ecosystem functions that are essential for the provision of ESS (Mace et al., 2012). The section below discusses this further.

Ecosystem Services in the context of the *RightSeeds* project

In the context of the *RightSeeds* Project, we adopt the definition from TEEB (2010) and consider ecosystem services (ESS) as "**the direct and indirect contributions of ecosystems to human wellbeing**". This conceptualization of ESS acknowledges the strong interlinkage between ecosystem functions and human wellbeing, while putting equal emphasis on the natural and social aspects. This makes it well suited for interdisciplinary contexts. Through the inclusion of indirect benefits, the importance of the interdependencies of various ecosystem functions and processes in the provision of ESS are highlighted. The definition's simple language allows for easy communication with stakeholders and thus serves well for transdisciplinary projects.

3.4.4 Ecosystem Services and Agrobiodiversity

The initial rationale behind the ESS concept was to demonstrate how the disappearance of biodiversity effects human well-being. While both the MEA and the TEEB acknowledge significant overlaps between biodiversity - of which agrobiodiversity is a subset - and the provision of ESS, the precise relationship often remains vague (Mace et al., 2012). On a conceptual level, some scholars have equated the two concepts, neglecting the socio-cultural aspects of ESS and falsely implying that the management of one will necessarily improve the other. Such conceptualizations do not adequately capture the multilayered relationship between these inherently complex concepts. Instead, we acknowledge that agrobiodiversity directly or indirectly influences all ecosystem functions and processes. As such, it may be regarded as a service that underpins the provision of all other ESS.

On an empirical level, there is a growing body of evidence demonstrating biodiversity's influence on ecosystem functions and processes (Balvanera et al., 2006; Cardinale et al., 2006; Hector & Bagchi, 2007). Although the social and ecological value of agrobiodiversity has long been recognized (Altieri & Merrick, 1987), causal evidence for agrobiodiversity, rather than biodiversity at large, remains patchy. A high degree of context-dependency of the provision of certain services and reinforcement loops between ecological processes and services, make it difficult to reliably isolate individual effects and draw robust conclusions (Frison et al., 2011). Furthermore, some of the benefits of agrobiodiversity are difficult to detect at the local scales at which the majority of agricultural experiments are conducted (Frison et al., 2011; Jackson et al., 2007). Nevertheless, the evidence for enhancing effects of high levels of agrobiodiversity on the provision of ESS have expanded significantly in recent years. A range of benefits, covering all four categories, have directly or indirectly been associated with agrobiodiversity (for an overview see table 1), highlighting its importance at all levels of the ecosystem service scheme. Below we briefly review each of these links. As previously specified, agrobiodiversity comprises diversity at various levels and includes genetic diversity, species diversity, and the diversity of agroecosystems. The relevance of diversity at a specific level varies with the ESS in question. Genetic diversity for instance plays a larger role in the provision of some regulating services, while species diversity is of high relevance for the provision of certain cultural services.

Ecosystem services		
Category	**Description**	**Service**
Provisioning Services	Products obtained from ecosystems	▪ Food and other agricultural products (e.g. Frison et al., 2011) ▪ Plant genetic resources (e.g. Kotschi, 2007)
Regulating Services	Services that contribute to the regulation of ecosystem processes	▪ Disease- and pest regulation (e.g. Letourneau et al., 2011) ▪ Pollination (e.g. Hajjar et al., 2008)
Cultural Services	Non-material services provided by ecosystems	▪ Traditional, local knowledge (e.g. Budowski, 1972) ▪ Cultural identity (e.g. Milcu et al., 2013) ▪ Aesthetic and spiritual values (e.g. Fish et al., 2016)
Supporting services	Services that allow for the presence of other ecosystem services	▪ Primary production (e.g. Hooper et al., 2005) ▪ Nutrient- and water cycle (e.g. Hajjar et al., 2008) ▪ Carbon sequestration (e.g. Hajjar et al., 2008)

Table 1: *Overview of ecosystem services that have been directly or indirectly associated with agrobiodiversity.*

Provisioning Services

Food: The capacity of our ecosystems to provide us with life-sustaining energy and nutrients is largely dependent upon the crops we are able to plant and harvest. A number of studies have demonstrated the importance of intra- (Chateil et al., 2013; Hajjar et al., 2008; Macfadyen & Bohan, 2010; Zhu et al., 2000) and inter-specific (Altieri, 1999; Lin, 2011) crop diversity to stabilize and increase yields[4]. Consequently, crop diversity has been positively associated with food security (Allen et al., 2014; Brussaard et al., 2010; Frison et al., 2011; Kahane et al., 2013). In the context of the Global South, it has also been linked to nutrition security. High levels of crop diversity buffer agricultural production

[4] These effects have primarily been attributed to improved pest control (see section below).

systems against rising weather extremes and increase farmer's likelihood of obtaining essential nutrients (Declerck et al., 2011).

Plant genetic resources: Present and future plant breeding depends upon the conservation of high levels of genetic variation in agricultural and wild varieties. While there are uncertainties about the occurring degree of loss of variation in crops on a genetic and species level (van de Wouw et al., 2010), there is no doubt that especially genetic diversity will be essential for future generations to meet their needs. High genetic in-situ diversity poses a prerequisite for the development of varieties that can cope with changing conditions such as shifting climate patterns or pests brought about by climate change (Frison et al., 2011; Kotschi, 2007). As a result, high genetic crop diversity on field and landscape scale strengthens societies' resilience and adaptive capacities (Lin, 2011; Petersen & Weigel, 2015).

Regulating Services

Pest & disease regulation: Pest regulation is one of the major benefits associated with crop diversification (Frison et al., 2011; Hajjar et al., 2008; Lin, 2011). A review of 45 studies found strong beneficial effects on the use of crop diversification schemes for herbivore suppression and reduced crop damage (Letourneau et al., 2011). Diversified agroecosystems are able to maintain a greater diversity of animal species, including natural enemies of crop pests (Altieri, 1999) and lower concentrations of hosts' plants may reduce attraction of specialist enemies (Sheehan, 1986). Crop diversity also contributes to the suppression of pathogenic diseases. Genetically diverse cultivar mixtures have been shown to limit polycyclic epidemics caused by airborne (De Vallavieille-Pope, 2004), as well as by soil- and seed borne diseases (Zhu et al., 2000).

Pollination: At local or landscape scale, crop genetic diversity has been theorized to contribute to more effective pollination services through sustaining greater pollinator diversity and through prolonged pollination periods caused by staggered flowering times among crop varieties (Hajjar et al., 2008). However, empirically evidence remains inconclusive and other factors such as proximity to and size of natural habitats (Kremen et al., 2002) or the presence of crop-associated companion planting (Pywell et al., 2005) may have larger impacts on the provision of pollinator services than crop diversity per se.

Cultural Services

Cultural ecosystem services differ from other services in that they are often intangible. They are understood not as a priori products of nature that people utilize for a particular benefit of well-being, but rather as being actively created and expressed through interactions with ecosystems. As such, they are co-produced outcomes. The emphasis lies here on the relational values that emerge out of the interaction between humans and their natural environments. Cultural ESS can thus be understood as the contributions that ecosystems make to human well-being through helping to frame identities and enabling experiences and the acquisition of capabilities.

Cultural identities: (Agro-)biodiversity is an essential constituent of many environmental spaces which serve as sites of diverse human-environment interactions. Aspects of biodiversity are often associated with culturally defined attributes such as beauty or originality. Thereby they lend themselves to specific cultural practices (symbolic, expressive or interpretative) from which humans derive non-material and non-consumptive benefits (Fish et al., 2016; Milcu et al., 2013). With traditional farming practices and lifestyles often being associated with a greater richness in crop varieties (Velásquez-Milla et al., 2011), agrobiodiversity gives rise to different traits of identity such as a sense of place and belonging, rootedness and spirituality.

Traditional local knowledge: The close connection between agrobiodiversity and local (agricultural) knowledge has been widely recognized (Nazarea, 2006) In the Global South, knowledge on how to grow and use cultivars in specific locations has traditionally been passed on to future generations and often accumulated over centuries (Banzhaf, 2016). Given that knowledge production is tightly interwoven with environmental spaces, the loss of agrobiodiversity brought about by changing agricultural practices affects the long-term preservation of knowledge (Budowski, 1972).

Spiritual and aesthetic values: Agrobiodiversity can increase the potential for encounters with elements of the environment, which people find spiritually enriching or aesthetically pleasing. Environmental spaces are replete with meaning and value for human beings that are constructed around and through nature. Hence, the conservation and cultivation of agrobiodiversity enables human-environment encounters, which are deemed inspiring, relaxing or enriching (Fish et al., 2016).

Supporting services

Primary production: Crop genetic diversity can enhance ecosystem's capacity to sustain biomass levels (Hajjar et al., 2008) and has been found to lead to increases in net primary productivity[5] (Crutsinger et al., 2006; Hooper et al., 2005). Case studies demonstrate that especially in less predictable environments such as areas with poor soil quality, swamp environments, areas with unpredictable rainfall, or on hill sides, genetic diversity can contribute to a more stable vegetation cover (for a review see Hajjar et al., 2008).

Nutrient- and water cycles: There is lack of consensus on the impact of crop diversity on soil dynamics and effects appear to be highly situation-dependent. While there is evidence that genotypic diversity can influence soil dynamics such as decomposition rates, nitrogen fixation and soil erosion, few studies have thoroughly explored this so far (Hajjar et al., 2008).

Carbon sequestration: Carbon storage in plants is highly species-specific and there is much uncertainty about the extent to which trait interactions between species affect carbon uptake (De Deyn et al., 2008). Consequently, crop diversity has rarely been associated with increased carbon sequestration. However, the positive effects of agrobiodiversity on productivity and slowed soil degradation may indirectly increase carbon sequestration rates (Hajjar et al., 2008).

[5] Net primary productivity is the rate at which an ecosystem accumulates energy or biomass, excluding the energy it uses for the process of respiration.

In conclusion, agrobiodiversity has been associated with a range of ESS. While there is no conclusive evidence on the provision of a number of individual services, the overall human benefit of diverse agroecosystems cannot be dismissed. On a broader scale, research shows that agrobiodiversity improves resilience of agricultural production and adaptability to environmental change and will consequentially be of central importance in climate change adaption (Lin, 2011; Lin et al., 2008; Mijatović et al., 2013; Petersen & Weigel, 2015). Nevertheless, ecological consequences are not predictable based on different levels of diversity alone (Hughes et al., 2008). For example, simply adding more genetic diversity to agroecosystems may have little effects on the ESS provided (Jackson et al., 2007), especially if functional saturation is reached (Swift et al., 2004).

3.5 Food Sovereignty

Food sovereignty is a concept that has been strongly advocated by civil society actors and countries of the Global South (and increasingly the Global North) to address the structural injustice in the food sector. It has emerged from the discourse on food security, but goes beyond its demands by not only claiming the sufficient availability of food resources but also drawing attention to power dimensions and the social control of productive resources for food production such as land, seeds and water.

Since food sovereignty arose as a response to the discussion on food security and the right to food, it can best be understood in demarcation to those two concepts. Therefore, the emergence of food sovereignty and its role in the international discourse will be presented in delimitation to food security and the right to food.

3.5.1 The Emergence of Food Sovereignty and its Demarcation towards Food Security and the Right to Food

The right to food is the oldest of the three concepts. It emerged after the Second World War and was codified as early as 1948 in article 25 of the Universal Declaration of Human Rights (UDHR) by the United Nations. In 1966, it was included in article 11 of the International Covenant on Economic, Social and Cultural Rights (CESCR). In both treaties, the right to food was mentioned as one aspect of the "right to a standard of living adequate for the health and well-being of himself and of his family" (Art. 25 UDHR and Art. 11 CESCR), but was not specified further.

Securing the availability of sufficient food supplies became a major concern in the 1970s. A severe world food crisis had hit many countries from 1972-1974, caused by fluctuations in food and oil prices, export restrictions and extreme weather events (Headey & Fan, 2010). The World Food Council (WFC) was founded as a response in 1974 to tackle these challenges on the international level. In the following negotiations, the concept of food security emerged. Food security, as presented in the report of the World Food Conference in 1973, aims at securing the "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (UN 1975, as cited by FAO, 2003, p. 27). This definition reflects the experiences of the World Food Crisis and the belief in the ability of states to redistribute if sufficient food resources are available (Patel, 2009). In addition to the global dimension, national food security was introduced in the FAO Plan of Action on World Food Security a few years later.

In the 1980s, the FAO and the World Bank further elaborated the concept of food security. The focus now shifted from securing supply in times of crises at the international or state level to assuring the access to (and the demand of) food at the household and individual level (FAO, 2003). Taking into consideration the widespread and chronic malnutrition associated with poverty, especially in less developed countries, the World Bank defined food security as “the access by all people at all time to enough food for an active and healthy life” (World Bank, 1986, p. V). The lack of access was primarily seen as a matter of lacking purchasing power that could be addressed with “supporting economic growth with an equitable distribution of income” (World Bank, 1986, p. V). Overall, in this period, conceptualizations of food security became more comprehensive and started to place more emphasis on economic and social dimensions. The perspective of the World Bank showed a strong trust in market solutions, which was further strengthened by the collapse of the Soviet Union in 1989. As Patel (2009) describes, the dominance of neoliberal capitalism in state-level diplomacy in the 1990s led to a perceived irrelevance of international organizations. A directly visible consequence was the dissolution of the WFC in 1994, whose tasks were resumed by the FAO and the World Food Programme (WFP). The decreased attention provided the opportunity for international organizations to advance controversial issues and civil society organizations to influence the discourse and to participate in decision-making processes on an international level (Patel, 2009).

Civil society organizations and progressive governments on the global level were now advocating the concept of food sovereignty that had emerged in the Global South in the 1980s parallel to the negotiations on food security. Food sovereignty had first been mentioned as a goal in a Mexican government program in 1982. In this program, the national independence in food production from foreign capital and imports along all steps of the production chain was promoted. The term was later adopted by peasant movements in Central America (Edelman, 2014). In 1988, during the negotiations of the Uruguay Round of the WTO, several countries of the Global South argued for the use of ‘food sovereignty’ as an alternative concept to food security. Their main objectives were the national self-determination of food production, a guarantee of sufficient supply and adequate prices, and new development opportunities on the basis of an increasing national production and consumption of food (Windfuhr & Jonsen, 2005, p. 35). In 1996, the international peasant movement *La Via Campesina* promoted the concept in their report “Food Sovereignty: A Future Without Hunger” as being:

> *“The right of each nation to maintain and develop its own capacity to produce its basic foods respecting cultural and productive diversity. We have the right to produce our own food in our own territory. Food sovereignty is a precondition to genuine food security.” (Via Campesina, 1996, p. 1).*

The aspect of rights that had previously played no role in the discourse on food security was linked to food security during the World Food Summit on Food Security summoned by the FAO. The Declaration on World Food Security reaffirmed the right to food as a precondition for food security. Additionally, the World Food Summit Plan of Action simultaneously demanded a more detailed interpretation of the right to food that had been codified almost 50 years earlier (Hönicke et al., 2007). Following this mandate of the summit, the CESCR provided a comprehensive definition in its General Comment No. 12 in 1999:

> *"The right to adequate food is realized when every man, woman and child, alone or in community with others, have physical and economic access at all times to adequate food or means for its procurement." (CESCR GC 12, para. 6)*[6].

The General Comment No. 12 is an important milestone in the fight against hunger, as it includes an obligation of the state to respect, protect and fulfill this right (CESCR GC 12, para. 15). The right to food is recognized as a human right. Therefore, it is binding and it prevails all other international law, as specified by the Vienna Declaration. Individuals can thus enforce this right by legal action. The FAO and most of its members acknowledge the right to food. In 2004, the FAO also passed a set of voluntary guidelines for the progressive realization of the right to adequate food in the context of national food security (Hönicke et al., 2007).

The Forum on Food Sovereignty in Havana in 2001 initiated an intensive international discourse and further elaboration of the concept of food sovereignty in a number of declarations, reports and forums of Non-Governmental Organizations (NGOs) and Civil-Society Organizations (CSOs). Food sovereignty shifted from being focused on the right of nations to addressing people, communities and finally individuals as subjects. This was again influenced by the advancements on the right to food: By including individuals as the carriers of rights to food or food production, a link to human rights was established (Windfuhr & Jonsen, 2005). Moreover, it impacted food security. In 2002, civil society actors were involved in the drafting of a report by the FAO on "The State of Food Insecurity in the World". A revised definition of food security was included that had a stronger social dimension:

> *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 2001, glossary).*

The concept of food sovereignty became more comprehensive and detailed in the following years, encompassing e.g. the right to define own agricultural policies. Aspects of ecologically and socially sustainable production were strengthened and the right of access to productive resources such as land and seeds became more explicit. In 2004, the Peoples' Convention on Food Sovereignty was drafted by the Asian civil society, building on previous definitions by the International NGO/CSO Planning Committee (IPC):

> *"By this Convention, Food Sovereignty becomes the right of people and communities to decide and implement their agricultural and food policies and strategies for sustainable production and distribution of food. It is the right to adequate, safe, nutritional and*

[6] General Comment No. 12, 1999 UN-CESCR Doc. E/C.12/1999/5.

> *culturally appropriate food and to produce food sustainably and ecologically. It is the right to access of productive resources such as land, water, seeds and biodiversity for sustainable utilization." (People's Food Sovereignty Network Asia Pacific & Pesticide Action Network, 2004, p. 35, Preamble 1.2 of the Convention).*

Another milestone for food sovereignty was the declaration of Nyéléni following the World Forum on Food Sovereignty. At this forum, food sovereignty moved beyond the production side. Food sovereignty became seen as a vision for common practices and exchange between producers and consumers at the local scale. Consumer's associations and the concerns of consumers such as the quality of food gained importance. Between 1999 and 2009 several countries included food sovereignty in their constitutions, including Ecuador, Mali, Nepal, Senegal, Bolivia and Venezuela (Wittman et al., 2010).

Looking at the historic development, the three concepts are strongly interdependent and have enriched one another over time. Despite differing proponents, foci and ways of effecting agricultural policy and the food system, in their essence all three concepts have the potential of being complementary approaches, rather than contradictory ones (Edelman, 2014).

The right to food is a legal concept. It addresses the individual and the society as a whole and encompasses enforceable duties of the state. Food security is more of a technical term and has been accepted as a policy goal by most states. It describes a target state, but not how this state can be achieved and it does not encompass any obligations. Food security has originated in the Global North and encompasses no political or power dimensions (Hönicke et al., 2007). Although the current definition addresses primarily the individual or household level, the original understanding of food security of a general availability of food on the global and national level still prevails as a norm in debates on the international level (Windfuhr & Jonsen, 2005).

Food sovereignty is a political term. Its origin lies in the struggle of countries of the Global South for more independence in agriculture and their own food production, but it has, by being adopted by actors of the civil society, evolved to a concept that aims at empowering people and communities. As was the case with food security, the concept has become more comprehensive over time. In contrast to food security and the right to food, which primarily address the access to food, food sovereignty focuses on the necessary productive resources such as land, seeds and the social control of these resources. It encompasses a strong cultural dimension. Food sovereignty does not only describe a target state, but criticizes the food and agricultural system as such and aims at transforming it (Wald & Hill, 2016). Thereby, it can serve as a mean to implement the right to food.

3.5.2 Key Elements of Food Sovereignty

A large variety of different conceptions exists from diverse political contexts and movements with different political foci. There are a number of position papers of NGOs and CSO (see overview in Windfuhr & Jonsen, 2005, p. 47f.). Most definitions contain the following elements:

- the priority of local agricultural production to feed people locally
- the access to productive resources such as land, water, seeds etc.
- the right to food
- the right of smallholder farmers to produce food and a recognition of Farmers Rights
- the right of consumers to decide what they consume, and how and by whom it is produced
- the recognition of the rights and the contribution of women to agriculture and food production
- the right to protect oneself from cheap agricultural imports
- the necessity to adapt agricultural prices to production costs
- dialogue and participation in agricultural policy decision-making
- the advancement of a sustainable agriculture
- agro-ecology as a way not only to produce food but also to achieve sustainable livelihoods, living landscapes and environmental integrity

  (adapted from Windfuhr & Jonsen, 2005, p. 13)

Definitions vary with regards to the precise combination of these elements of food sovereignty and the priority given to different aspects such as sustainable modes of production or the position with regards to the role of trade in food systems. Building on the variety of definitions, four pillars of food sovereignty were identified during the Forum on Food Sovereignty in 2002. They present the priority areas for action for food sovereignty:

- right to food
- access to productive resources
- mainstream agro-ecological production
- trade and local markets (Windfuhr & Jonsen, 2005, p. 14f.)

Differences and conflicts exist particularly with regards to the measures that are necessary for the implementation of food sovereignty (Windfuhr & Jonsen, 2005).

3.5.3 Gender and Food Sovereignty

The role of women in agriculture and food production strongly influenced the discourse on food sovereignty right from the very beginning. To address the low representation of women and the neglect of their concerns at the first international meetings of the peasant organization La Via Campesina, a special committee was installed that subsequently promoted gender equality in the organizational structures and the discourse on food sovereignty as a whole: The Women's Committee of La Via Campesina. As a consequence, when the concept of food sovereignty was presented at the World Food Summit in 1996, aspects of gender equality were already highlighted in the concept, e.g. the need to include women in the definition of rural policies (Desmarais, 2007).

Considering gender equality in food sovereignty is essential for two reasons. Firstly, women contribute the biggest share of agricultural produce in the Global South and are also the main processors. Especially for domestic production, women play an important role. Secondly, women face a substantial amount of discriminations. Women have systematically less access to land and capital than men. Most paid activities in agriculture are undertaken by men (sales on markets or to the industry). Additionally, they face more uncertainty as they are particularly vulnerable to be deprived of their access to land or resources, not only by states or corporations, but also by male relatives (Edelman, 2014). Women are often not culturally eligible to inherit land or farms and it is difficult for them to obtain loans or land. They are also paid lower wages for their work. When access to food is dependent on market conditions, this increases their risk of hunger (Patel, 2012).

Hence, there are structural differences between women and men in agriculture that need to be addressed systematically in the concept of food sovereignty (Park et al., 2015). Social differences such as class, gender and ethnicity need to be taken as a starting point for analysis, especially in a concept that distinguishes itself from other approaches by its strong political dimension and its regard for power relations. For doing so, La Via Campesina as one of the main actors in the discourse on food sovereignty, has established numerous alliances with various women's rights organizations and movements, like the International World Mach of Women. 'Gender justice' has consequently been confirmed as a central pillar of food sovereignty, e.g. in the *Women of La Via Campesina Manifesto* (Via Campesina, 2013).

3.5.4 Seed Sovereignty

Seeds are the foundation for any form of agriculture and food production. Therefore, the access of farmers and other producers to seeds is an integral part of food sovereignty (Kloppenburg, 2014). However, the free availability of seeds is being limited especially for small-scale farmers through attempts to increasing commercialization, privatization (seed and variety registration regulations, patenting and licensing) and concentration of power in the seed sector. In response to this threat, a number of organizations and initiatives have emerged that aim at preserving the 'seed freedom' or 'seed sovereignty'. For example, the two organizations *La Vía Campesina* and *Navdanya* (founded by the Indian activist Vandana Shiva) have been working on and bringing forward the issues of seeds in the context of food sovereignty for several centuries. More recently, the European Campaign for Seed-Sovereignty (CSS) emerged as a response to the revision of EU regulation on the marketing of seeds in 2008 (CCS, 2008).

In an attempt to highlight the particularly important role of seeds for a sovereign food system and the need to preserve seed freedom, Kloppenburg (2014) has outlined key dimensions of seed sovereignty, building on the publications of the two organization *La Vía Campesina* and *Navdanya*. Accordingly, seed sovereignty encompasses the following four dimensions (Kloppenburg, 2014, p. 1234f.):

- The right to save and replant seeds: At the core of seed sovereignty is the rejection of legal or technical mechanisms that prevent the reproduction of seeds by farmers such as patenting or the breeding of hybrids.
- The right to share seeds: Besides saving and replanting one's own seeds, the right to share seeds with others is essential in many traditional and informal farming systems. A free seed exchange has contributed to crop genetic diversity for centuries. However, seed regulations at the international and EU level that require the registration of seeds threaten to restrict this exchange.
- The right to use seeds to breed new varieties: This entails the right of farmers to develop new breeds that are adapted to their specific requirements and preferences. This aspect is important with regards to changing conditions e.g. in face of climate change and for developing varieties for a resilient, sustainable agriculture.
- The right to participate in shaping policies for seeds and varieties: As for food sovereignty, seed sovereignty can only be achieved through a democratic participation of farmers, consumers and seed initiatives in legislative action. The increasing monopolization and power concentration threatens the influence that smaller initiatives can take on the formulation of seed policies. Both La Vía Campesina and Navdanya have published proposals and declarations on seed policies to advance the public discourse on the international level (see 'The Law of the seed' (Shiva et al., 2013) or 'Bali seed declaration' (Vía Campesina, 2011)).

Power dimensions, legal or bio-technical restrictions have much stronger implications for the access to seeds as a productive means for food production than e.g. a limitation of the general availability of resources. The political dimension of food sovereignty is therefore very useful in this context.

3.5.5 Food Sovereignty in the Context of the Project RightSeeds

To account for the importance of seed sovereignty, the definition of food sovereignty in the context of the project *RightSeeds* will encompass its central elements. However, since the project attempts to analyze the transformative potential of *Seed and Variety Commons* on the agricultural regime and the food system as a whole, e.g. with regard to achieving the Sustainable Development Goals, it will preserve the more comprehensive perspective contained in the concept of food sovereignty. Consequently, the following understanding of food sovereignty will be used in the context of the project *RightSeeds*.

Food sovereignty is the right of individuals and communities at the local, municipal or regional level (People's Food Sovereignty Network Asia Pacific & Pesticide Action Network, 2004) to access sufficient and healthy food and its productive resources and to control their own food systems, including land, water, seeds and natural resources (Via Campesina, 1996). This includes the right to save and replant seeds, share seeds and breed new varieties (Kloppenburg, 2014). Producers and consumers have the right to culturally adapted agricultural and seed policies, which are determined in a democratic and just manner, including the equal participation and appreciation of men and women (Patel, 2012; Via Campesina, 1996). Food sovereignty entails the priority of local production, supplemented by fair trade relationships (Via Campesina, 2001), as well as the possibility to develop the capabilities for autonomous food production and the respect of cultural and productive diversity (Via Campesina, 1996). Food Sovereignty includes the responsibility to ensure ecologically sustainable practices that guarantee the conservation of the natural resources that build the foundation for food systems for future generations (Via Campesina, 1996). The state is in duty to guarantee frame conditions, which at least do not oppose and ideally promote food sovereignty. Communities promote and ensure food sovereignty for each individual within the community and the community as a whole (see Edelman, 2014).

This conceptualization of food sovereignty is a comprehensive one that includes strong cultural and political dimensions. While having its origins in the Global South, we argue that food sovereignty can have also important implications for industrialized countries. We recognize the transformative potential of food sovereignty and its connectivity to current trends and initiatives such as Community Supported Agriculture or Urban Gardening. Its democratic and participatory character leaves room for individual solutions for different regions that must be subject to intense negotiation processes. For instance, the roles of consumers and producers or the relevance of trade could be important points for debate. We are aware of the potentially opposing interests in this definition. For example, in the current situation, the high costs of organic production and tight budgets of low-income groups could result in a conflict between affordable food and sustainable practices. A prioritization of different aspects of food sovereignty must be negotiated democratically. A resolution of this dilemma might require a radical social-ecological transformation of economic structures that goes well beyond the food sector.

3.6 Social-Ecological Transformation

Transformation is a concept that is frequently being used in the literature on sustainability science. In its core, a transformation is a profound, substantial and irreversible change which involves the alteration of fundamental attributes of a system (Brand et al., 2013; Feola, 2015). This includes changes in structure (e.g. institutions, culture) and in agency (empowering people to envision and implement alternative pathways) (Brown et al., 2013).

The concept of transformation has been used to analyze and explain current and historical processes of change from an analytical-descriptive perspective (Brand et al., 2013). An example provides the ‘great transformation’ from the agrarian to the industrial society (Polanyi, 1944). With regards to global environmental challenges, such as climate change, the term ‘social-ecological transformation’ is often employed in a normative-strategic sense. A number of international organizations (e.g. ISSC & UNESCO, 2013; UNEP, 2012; WBGU, 2011) call for large scale societal changes towards sustainability, which address current environmental and social issues. Proposed solutions include the adoption of a new economic system, new social contracts and new understandings of prosperity (Brand et al., 2013).

3.6.1 Key Issues in Transformation Discourses

Understandings of transformation in the literature are diverse, fragmented and often highly contested (Fazey et al., 2017; Feola, 2015; Fischer-Kowalski & Haberl, 2007; Gillard et al., 2016)[7]. Key points of contention in the conceptualizations of transformation are (a) the depth and quality of change: At which level (individual, organization, governance, system) does the change occur; (b) the breadth: What kind of system (social-ecological system, socio-technical system) or subsystem (energy sector, agricultural sector) is considered; (c) the speed or timeframe: Is there incremental and/or rapid change; and (d) whether the change is deliberate or emergent (Fazey et al., 2017). The understandings of what is considered as transformative change differ along these dimensions depending on the context in which the concept of transformation is employed. Fazey et. al (2017) argue that a single agreed concept or definition of transformation across all disciplines and contexts might not be possible or desirable. Therefore, it is important to "be explicit about from what and to what something is being transformed" (Fazey et al., 2017, p. 3).

Depth [8]

Most transformation concepts consider structural changes and view systems as complex, dynamic and multilevel entities. Accordingly, transformations take place on multiple spatial scales and functional levels (markets, states and civil society). Some theories of transformation, such as Deliberate Transformation (O'Brien, 2012), Progressive Transformation (Pelling, 2011), Transformational Adaptation (Kates et al., 2012) and Social Practice (Shove et al., 2012) include the individual level. Other theories including Societal Transitions (Grin et al., 2010), Regime Shift (Folke et al., 2010; Walker et al., 2004) and Socioecological Transition (the Viennese sociometabolic transitions approach) (Fischer-Kowalski & Haberl, 2007), which consider only meso and macro levels.

In an influential article, Meadows (1999) identified a hierarchical list of leverage points for system change ordered by increasing effectiveness. Moreover, she depicted their embeddedness in the deeper structuration of the system and how hard it is to influence them accordingly.

[7] This paragraph outlines the scope of the discourse on transformation, but cannot provide a comprehensive literature review. For more detailed discussions see: Fazey et al., 2017; Feola, 2015; Fischer-Kowalski & Haberl, 2007; Gillard et al., 2016.

[8] For the classification of transformation concepts, the literature considered and the analysis of their features draws heavily on Feola (2015).

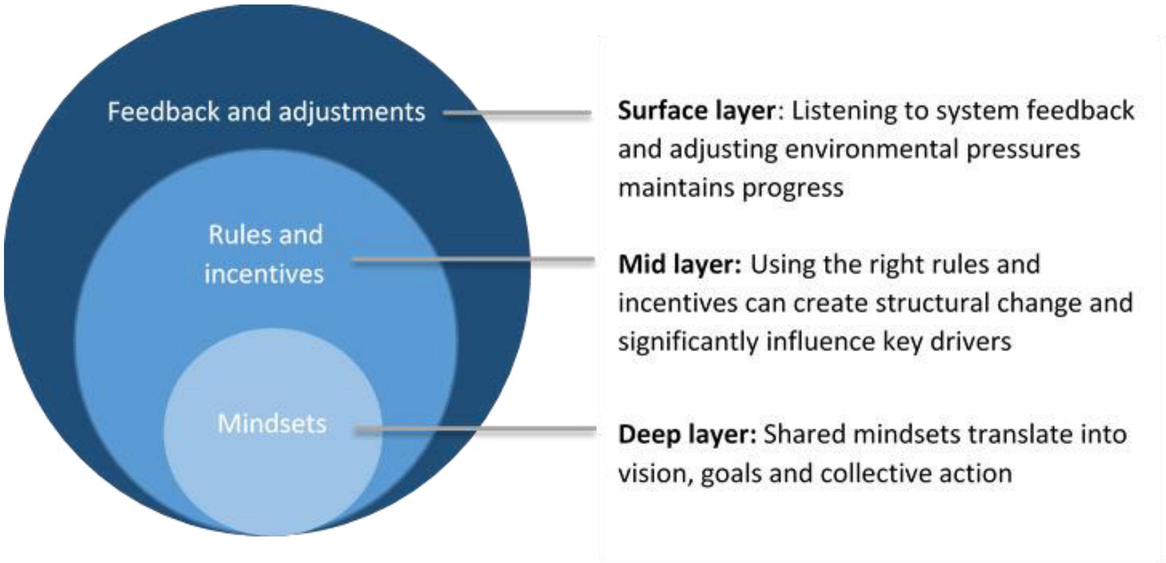

Figure 3: *Layers of leverage in system innovations (Göpel, 2016, p. 43, fig. 2.4, citing UNEP, 2012)*

In more recent research, mindsets and paradigms have been identified as the vital leverage points for transformation (see fig 3.) (Abson et al., 2017; Göpel, 2016; Meadows, 1999). Rules and incentives are also considered to be essential tools since they can create structural change by influencing key drivers. Contrasting, system feedback and adjustment to environmental pressures are described as having little impact (Göpel, 2016).

Breadth

What kind of system is considered in transformation concepts (the breadth of transformation) differs largely. Some approaches consider society at different levels, ranging from the local to the global level (*Socioecological Transition, Social Practices*). Other approaches (*Regime Shift*, *Societal Transitions*, *Transformational Adaptation*) are applied to a wider range of systems, including to specific subsystems (for instance ecosystems or productive sectors). The literature on social-ecological transformation acknowledges the need for profound changes to production and consumption patterns. It is also widely recognized that technical innovations are a necessary, but not a sufficient criterion for a social-ecological transformation. Rather, social innovations are central to transformations (Brand et al., 2013).

Timeframe

Changes considered as transformative tend to go beyond incremental changes. They are non-linear, dynamic processes that occur in complex systems with potential tipping points (Fazey et al., 2017). Accordingly, they are subject to ruptures, discontinuities and thresholds. Cycles and phases are often used to conceptualize these complex behaviors, without attempting to describe definite features (Feola, 2015). For example, in the context of *Regime Shifts* a transformation is composed of three phases: The preparation of social-ecological systems to changes, the navigation of change (e.g. by using a window of opportunity) and the building up of resilience in the new social-ecological regime (Folke et al., 2010). *Socioecological Transition* mostly considers long timescales, such as the industrial revolution, while *Societal Transition* refers to shorter time spans of several decades (e.g. 40-50 years). Theories that build upon the concept of resilience, such as *Deliberate Transformation* and *Progressive Transformation*, highlight that a distinction between short and long-term time ranges is not distinct. Incremental change can result in transformational change when certain thresholds are passed (Folke et al., 2010). Similarly, Göpel (2016) argues that changing mindsets can connect radical and incremental aspects of change strategies. He points out that "radically different imaginaries of potential future developments influence the formulation of new goals for the system that can then be implemented step by step, changing the rules, procedures and norms accordingly" (Göpel, 2016, p. 41). In *Transformational Adaptation*, there is a quite clear distinction between transformative and incremental change: The level where change is observed is the defining characteristic of a transformation. Adaptive change is classified as transformative when it is scaled up, for example from the local to the regional level (Kates et al., 2012).

Deliberate / Emergent

There is consensus in the literature that a transformation is a process that combines endogenous and exogenous elements, involving both emergent, unintended consequences and intended, deliberate ones (Shove & Walker, 2007). Some approaches, e.g. *Socioecological Transition* and *Social Practice* emphasize emergent processes, while others, like *Deliberate Transformation* and *Regime Shift*, focus on deliberate processes. Deliberate change refers to the possibility of steering, navigating or even fully managing the process. It highlights the central role of agency (Brown & Westaway, 2011; Nelson et al., 2007; O'Brien, 2012; Pelling, 2011). In face of current challenges such as climate change or biodiversity loss, the assumption that taking influence is possible at least to some degree is central in the discourse on social-ecological transformations. This poses many questions as to for whom influence is taken and who should decide about the direction of change (Fazey et al., 2017).

3.6.2 Transition vs. Transformation

This brief overview of the differing conceptualizations of transformation shows the wide diversity and difficulty to find a common conceptual understanding of transformations. Brand (2012) proposed to differentiate between the terms transformation and transition as this distinction is often not consistent in the literature. This demarcation can help to specify the scale of change that is regarded along the categories of quality, breath, timeframe and deliberate/emergent. According to Brand (2012), transitions are intentional processes of change that are aimed at achieving specific, previously defined goals. Transitions take place in subsystems, often in the field of technology, and are assumed to be manageable. On the other hand, a transformation is a more comprehensive, fundamental system change that encompasses changes in socio-economic, political and cultural spheres (Brand, 2012). A transformation can be composed of transitions in several subsystems.

3.6.3 Social-Ecological Transformation and Resilience

Many transformation theories have their roots in resilience theory, which provides a profound understanding of the complex dynamics of social-ecological systems (e.g. *Regime Shift*, see Folke et al., 2010; Olsson et al., 2014; Walker et al., 2004), often combined with other theoretical approaches, such as political ecology (*Deliberate Transformation, Progressive Transformation*) or transition theory (Feola, 2015). Therefore, to further the understanding of the system dynamics underlying social-ecological transformation, it is essential to consider the concept of 'Social-Ecological Resilience' (SER). Resilience thinking focuses on the capacity of tightly coupled social and ecological systems to deal with both unexpected shocks, such as extreme whether events or economic crisis, and ongoing change, such as soil degradation or change in consumer preferences (Biggs et al., 2010; Folke, 2016). While SER has often been equated with regaining stability after disturbances, more recent contributions (Bousquet et al., 2016; Brown, 2016; Folke et al., 2010; Moore et al., 2014) link the concept to profound change and transformation. Regime shifts are at the core of resilience thinking and provide the central link to transformation discourses. In SER-research, transformability is defined as "the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable" (Folke et al., 2010). The importance of shifting resilience of existing systems into new stability domains (for stable states) is discussed as a requirement for the persistence of crucial ecological system functions at the global level, operationalized as planetary boundaries (Folke et al., 2010). Resilience scholars emphasize that transformational change involves commitment to experimentation and social innovation, shifts in power relations and institutional arrangements as well as changes in norms and values (Folke et al., 2010; Schoon et al., 2011; Westley et al., 2011). SER, if operationalized as a property of specific social-ecological systems (Carpenter et al., 2001), has been evaluated - with reference to certain socially desirable objectives - using sets of indicators that capture system properties and characteristics of the governance system. Such evaluation frameworks (as applied by Cabell & Oelofse, 2012 to agricultural systems) may prove valuable for assessing whether a change process should be considered a social-ecological transformation.

3.6.4 Social-Ecological Transformation in the Context of RightSeeds

The current agricultural system faces complex challenges that require fundamental structural changes to ensure long-term food security and food sovereignty (see the project description of *RightSeeds*). *RightSeeds* takes a normative perspective by evaluating how SVCs can contribute to a social-ecological transformation of plant cultivation, while relying on descriptive and analytical aspects for understanding current and past dynamics. Concerning the depth of change, the system level as a whole is considered. However, individual sub-studies/working packages place a focus on specific levels such as the individual, the organizational or the governance level and their interactions. Changes in plant cultivation concern aspects of ecology as well as societal changes. Therefore, the project of *RightSeeds* considers changes in agriculture as a social-ecological subsystem (breath).

Transformations are complex processes that are difficult, if not impossible, to navigate. As described above, they occur over very long time frames and are comprised of both emergent and deliberate features. A social-ecological transformation involves a high level of uncertainty, as well as a huge variety of different actors and complex interdependencies (Leach et al., 2010). Consequently, a precise target state of a social-ecological transformation is difficult to define. Moreover, democratic and justice considerations demand that a social-ecological transformation is the result of a deliberative process, instead of being defined beforehand and for all (Leach et al., 2010). As emphasized by resilience discourses, transformational change involves a change in power relations, institutions and new creative solutions that are robust and provide stability in the face of crises (Folke et al., 2010; Schoon et al., 2011; Westley et al., 2011). Taking these considerations into account, the project *RightSeeds* proposes a process-oriented understanding of a social-ecological transformation.

Social-Ecological Transformation of the agricultural regime is understood as a process that is open-ended, inclusive and empowering to marginalized actors (such as peasant and organic farmers), acknowledges different forms of knowledge (including local and culturally-specific knowledge) and ideas, and that strives towards food sovereignty and a high level of agrobiodiversity, with the objective of creating more socially just and resilient food systems.

3.7 Commons

Commons encompass the collective management of goods or resources. The term is presently used to refer to both the goods themselves as well as to the social institutions and practices used to sustainably govern them (Helfrich, 2012; E. Ostrom, 1990). The understanding of Commons has evolved and became more diversified in the scientific discourses of the past decades. To explain resource-use dilemmas, economic conceptualizations originally provided a technical classification of goods according to their qualities: Only resources that have a low degree of exclusivity (the effort to exclude others from their use is high) and a high degree of rivalry (the consumption of a good by a person reduces the possibility of the consumption of this good by others) were classified as Commons (Gordon, 1954; Scott, 1955). However, conceptualizations of Commons have developed over time to be more context-sensitive and interdisciplinary. Especially in civil society contexts and Institutional Economics, they are now viewed more broadly as a new way of organizing social relations. As such, they are understood as a social practice of managing resources collaboratively (Helfrich & Bollier, 2015; E. Ostrom & Hess, 2007). The understanding of Commons thus shifted from a type of good with clearly defined characteristics to a social practice of self-organized resource management.

Commons encompass three dimensions: (1) A material dimension - the resource itself (e.g. water, land, forest, software); (2) a social dimension - the user-community that uses the resource of interest and (3) a regulative dimension - the rules and norms concerning the usage of the resources, which are mostly decided upon by the user community (Helfrich, 2009). To gain an in-depth understanding of

Commons, the historical development of the concept is outlined below and the term is consecutively defined in the context of the *RightSeeds* project.

3.7.1 Historical Development of the Concept

The concept of the Commons originated in the field of economics in the mid-20th century and has since strongly evolved in its conceptualizations and fields of application. In his publication "The Pure Theory of Public Expenditure" Paul Samuelson (1954) first suggested a division of goods into two categories: Private and public goods. Public goods were characterized by non-exclusivity and non-rivalry. Thus, they are goods whose consumption by one person does not prevent the simultaneous consumption by others (non-rivalry), and whose potential users cannot be effectively excluded from consumption (non-exclusivity; e.g. the light of a street lantern). Contrasting, private goods are rival and exclusive. When an individual consumes a private good, it gets 'used up', meaning someone else cannot consume it and others can be excluded from consumption (e.g. an ice cream). Building on this classification, Commons came to be understood as a third, distinct category of goods that is characterized by rivalry on the one hand and by non-exclusivity for all actors of a market on the other hand (Gordon, 1954; Scott, 1955).

The scientific discussion about common goods gained momentum in 1968, when Hardin's famous article 'The Tragedy of the Commons' was published in the Science magazine. Based on the premise that users of common goods have no rights or obligations, Hardin believed that common goods will inevitably degrade due to the problem of overconsumption and free riding. A pasture, open to all, serves as his well-known example to the argument that common resources are necessarily used inefficiently. As rational actors, each herdsman has an interest in maximizing his individual profit and keeping as many cattle on the pasture as possible. The consequence is an overgrazed, degraded pasture. Hardin's article, which has been widely discussed in the scientific community, has frequently been used as an argument for the necessity of privatizing Commons (Berkes et al., 1989; Gibson et al., 2002). However, Hardin's thesis has been refuted on the basis of overly simplified assumptions (Feeny et al., 1990). In particular, the assumption that all common goods have open and unrestricted access has been heavily criticized (Feeny et al., 1990; E. Ostrom & Hess, 2007), as Commons theories presuppose that user-communities of common-pool resource develop social institutions to restrict access. Building upon these discourses, Runge (1981) refutes conceptualizations of Commons as prisoner dilemma and proposes the development of institutional arrangements as a solution to the free rider problem. Overgrazing, he argues, is not the result of selfish decisions of individuals, but rather the result of the inability of the community to coordinate the interdependent decisions of its members. This coordination, he proposes, can be achieved through institutions, which are rules of conduct that are shaped by conventions or by organizations such as companies or political groups (Runge, 1984, 1986). Thus, the definition of Commons was expanded to not only include the resource itself, but also its management through norms, rules and social institutions, which are negotiated and established by the community of its users.

The successive development of the theoretical concept of the Commons is primarily associated with Elinor Ostrom. While still referring to classifications of Commons in terms of rivalry and non-exclusivity, Ostrom added social-institutional dimensions as even more defining criteria of Commons. This addition is reflected in Ostrom's (1990) distinction between 'common-pool resources', the physical resource at stake, and 'common-property regimes', the social structures, including the norms, rules and institutions that enable the joint, sustainable management and use of a resource. To gain a better understanding of these institutions and their functioning, Ostrom developed the 'Institutional Analysis and Development Framework', a systematic analysis tool that sheds light on the ways institutions operate and change over time. At the center of the model are actors and their decision-making capacities. Institutions are thus considered to be human-centered systems that are shaped by and depend upon the decisions and characteristics of the actors involved (Hanisch, 2010; McGinnis, 2015; E. Ostrom, 2010b).

Public goods: A category of goods that is characterized by non-exclusivity and non-rivalry.

Common-pool resources: A common-pool resource, also referred to as common property resource, is a type of good consisting of a natural or human-made resource system (e.g. an irrigation system or fishing grounds), whose size or characteristics makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use (E. Ostrom, 1990).

Common-property regime: The social structures, including the norms, rules and institutions that enable the joint, sustainable management and use of a resource.

Commoning: The collective development of norms and rules that regulate the management of the common at stake.

Commons-based peer production: Collaborative decentralized means of production and open innovation processes often associated with digital Commons.

Ecommony: A concept to advocate the need to move beyond consumerist societies and private ownership towards lived practices of alternative economies.

Much of Ostrom's work has been devoted to the question under which conditions user communities are able to effectively manage common-pool resources at the local level. A major difficulty in the development of management rules lies in the fact that no general set of rules applies to all common-pool resources. Successful institutional arrangements are highly context-dependent and must be adopted to the physicality of the resource and the user-group (Acheson, 2011).

However, based on her findings from multiple case studies of long-lasting, effective resource-management systems, Ostrom (1990) developed eight 'design principles' for the sustainable use of common-pool resources.:

1. Clearly defined group boundaries: The identity of the user group and the boundaries of the shared resource are clearly delineated. The effective exclusion of external unentitled parties is ensured.

2. Proportional equivalence between benefits and costs: Provision rules are coordinated with withdrawal rules, so that the costs and benefits of the Commons are distributed proportionally between the individuals.
3. Collective-choice arrangements: Those affected by the rules can participate in modifying the rules. Decisions are made through collective-choice arrangements that allow resource users to participate in the set-up of the management.
4. Effective monitoring: The use of the Commons is monitored at low cost and by monitors who are part of or accountable to the appropriators.
5. Graduated sanctions for rule violators: Violations of rules can be sanctioned. Sanctions begin at a low level, but exacerbate with repeated violations.
6. Accessible, low-cost means for dispute resolution: Conflict resolution mechanisms should be in place to address conflicts and possible exploitation within the group.
7. Rule-making rights of community members are respected by outside authorities: There is at least minimal recognition by higher-level authorities of the right of the local people to organize and self-govern.
8. Nested enterprises: If a common-pool resource is directly connected to a larger social structure, rules need to be in place and enforced through multiple layers. Common-pool resource management units must thus be arranged in a nested hierarchy (Wilson et al., 2013).[9]

Another contribution of Vincent and Elinor Ostrom's work lies in their precision of the criterion of rivalry. Instead of conceptualizing rivalry as a binary, they introduced the concept of 'substractability', which describes the gradual nature of the rivalry of goods. They argue that the benefits of a rival good for one actor is not necessarily lost through its use by another actor but that depending on the good this is diminished by different degrees (E. Ostrom & V. Ostrom, 1977). On this basis, they further adapted the classification of goods proposed by Gordon (1954) and Scott (1955) into a classification of four types of goods according to the difficulty of excluding users and the substractability of use (see fig. 4).

		Substractibility of use (formerly rivalry)	
Difficulty of excluding potential beneficiaries		Low	High
	Low	Toll goods	Private goods
	High	Public goods	Common-pool resources

Table 2: *Four basic types of goods (adapted from E. Ostrom, 2005, fig. 1.3)*

[9] When applied to resources, which have not formerly been managed as Commons, these theoretical principles for the successful management of Commons have in some cases led to unsatisfying results in practice, especially in the context of Community-Based Natural Resource Management (CBNRM) (Blaikie, 2006; Dressler et al., 2010; Shackleton et al., 2010). This has been explained by the difficulty to purposefully generate common norms and participation in communities were these are not already present (Saunders, 2014). Consequently, it has been argued that a relatively high level of pre-existing social capital is crucial for the successful management of common-pool resources (Levine, 2001).

Also, the criterion of exclusivity as a defining characteristic of Commons has been challenged by various scholars. A good is considered to be non-excludable if it is technically difficult to exclude others from its usage or if the implementation of the exclusivist measures is disproportionately expensive or socially unacceptable. However, already Buchanan (1965) pointed out that „if the structure of property rights is variable, there would seem to be few goods the services of which are non-excludable, solely due to some physical attributes". Various examples demonstrate that the degree of excludability of a good is not necessarily permanent (Engel, 2002), but varies with technical and social innovations. The breeding of hybrid varieties provides an example of technological developments that have altered the degree of exclusivity of seeds. Seeds are naturally self-reproducing, making exclusion of users difficult. However, CMS-hybrids (cytoplasmatic male sterility-hybrids) grow sterile seeds, whose further use for the agricultural sector is limited, which necessitates farmers to annually re-buy seeds. Similarly, the strengthening of private property rights through the introduction of patents and licenses in the seed sector are examples of social innovations that have influenced the ability to limit users' access to seeds. These legal arrangements have an impact on farmers' rights to use, sell and breed varieties. Hence, the degree of exclusivity of a good is variable and partially depends upon technological developments and social arrangements. Helfrich (2012) consequently argues that exclusivity is not an inherent trait of a good, but is at least in parts a social creation.

3.7.2 Recent Conceptualizations of New Commons

Building upon the above outlined developments, in more recent conceptualization of 'New Commons' (Hess, 2008), Commons are not viewed as given, but as actively created. Beyond analyzing property right regimes, the study of New Commons places emphasis on collective action, voluntary associations and collaboration (Hess & Meinzen-Dick, 2006). In this context, Commons are understood as organizing principles that allow for the collective creation and sustainable management of resources through (more or less) defined user communities. The collective development of norms and rules that regulate the management of the Commons at stake is central here. This social process has been referred to as 'commoning' (Linebaugh, 2008) and underlines social commitment and shared knowledge (Helfrich & Bollier, 2015). This strand of literature documents the rationales and mechanisms for collective governance and analyses who shares what and how.

If Commons are socially created, it follows that legal and technical vehicles such as copyright protection or patent law enable the retransformation of newly established Commons into private goods (Elliott, 2005; Gepts, 2004). Academic and activist discourses consequently continue to address the question, which institutional designs allow for the long-term protection of Commons. Moreover, contributions of Commons to democratization, global sustainability objectives and the re-embedding of the economy (see Polanyi, 1944), have been highlighted by (social)-ecological economists (Hansen et al., 2016; Spash, 2017). Building upon these normative approaches to Commons, a social movement has formed.

Advocates of the Commons movement argue for the need to move beyond consumerist societies and private ownership and towards lived practices of alternative economies. This is expressed in the term 'ecommony' (Habermann, 2016). Through the movements critique on consumerism, it closely links to other social movement such as the degrowth movement or the South American philosophy of 'buen vivir' (good life; Gudynas, 2011; Habermann, 2016; Helfrich & Bollier, 2015; Linebaugh, 2008).

The theoretical broadening of the concept of Commons is reflected in the continuously increasing range of types of Commons that are scientifically analysed. It is also linked to a growing number of discourses and scientific publications on the 'new' Commons (Hess, 2008). In the context of the early conceptualization of common pool resources, Commons were by definition natural resources. The scope of scientific publications was consequently limited to a few economic sectors, such as agriculture, fishing, forestry or nature conservation. Later studies examine infrastructure (Waller, 1986), national budgets (Shepsle, 1983), radio waves (Soroos, 1982) or the intellectual public domain (Boyle, 1992; Merges, 1996). The conceptual development towards Commons as organizing principles has led to a further broadening of the fields of study. Most noticeably, the addition of digital Commons such as the internet (Hess, 1995; Kollock & Smith, 1996) and open-source software (Schweik, 2007; Van Wendel de Joode et al., 2003) have shaped scientific and public discourses around Commons in recent years.[10] The multitude of New Commons has been categorized according to four categories: Natural (water, fisheries, biodiversity etc.), social (public parks, spaces etc.), cultural (language, customs, knowledge etc.) and digital (tests, sounds, films etc.) Commons (Helfrich, 2009). However, various other categorization schemes of the New Commons have been developed in recent years (e.g. Benkler, 2003; Hess, 2008).

A recent phenomenon is the emergence of Knowledge Commons. They encompass the 'institutionalized community governance of the sharing and, in some cases, creation, of information, science, knowledge, data, and other types of intellectual and cultural resources' (Frischmann et al., 2014, p. 3). Knowledge Commons, which are typically non-rival, prove especially challenging for defining appropriate design principles (E. Ostrom & Hess, 2007). It is argued that exclusive measures, such as the introduction of property rights, can set incentives to enhance creativity and produce intellectual resources, but on the other hand, limit resources' availability to the general public (Frischmann et al., 2014, p. 3). Furthermore, some researches argue that Commons structures in the field of information, culture and knowledge promote gains in economic efficiency and innovation capacities in addition to benefits of individual freedom and democracy (Benkler, 2003; Benkler & Nissenbaum, 2006). Through the emergence of digital Commons and especially open-source software, a type of Knowledge Commons, a recent focus in Commons discourses has been on collaborative decentralized means of production. In the context of digital Commons, independent users continuously develop, test and collectively improve products and services (Benkler, 2002; Moor, 2015).

[10] Notice that this was only possible with the reconceptualization of Commons, since these resources, which nowadays are prominent examples of Commons, would not have been classified as such when categorized solely by their rivalry and exclusivity status.

This diminishes the need for a defined user group. Contrasting to Commons characterized by a high degree of rivalry (e.g. a pasture) which require a clearly defined user group for effective management, less- or non-rival Commons such as digital Commons only unfold their full potentials through free access management systems (Helfrich, 2012; Heller, 1998). Such open innovation processes have been referred to as Commons-based peer production (Benkler, 2006). Commons-based peer production also plays a central role in the acquisition or provision of information and knowledge. Platforms such as Wikipedia, or specialist scientific information portals, have proven that the production of knowledge by coproduction of independent developers can under certain circumstances be more efficient than the production of knowledge by a few experts (Seid et al., 2014). New legal arrangements such as copy-left principles, an arrangement whereby software or artistic work may be used, modified, and distributed freely on condition that anything derived from it is bound by the same conditions, have developed to institutionalize these developments in the context of pre-existing legal frameworks.

Commons in the context of the *RightSeeds* project

In the context of the *RightSeeds* project, Commons are conceptualized as the social structures - the norms, rules and institutions - that enable the collective creation, sustainable, joint management and use of a resource (E. Ostrom, 1990; Hess, 2008; Helfrich & Bollier, 2016). The resource is shared by a (more or less closed) user community, which is often characterized by a high degree of self-organization. It bears the responsibility to ensure the long-term provision of the resource. Individuals, companies, and organizations cannot gain exclusive control, e.g. through property rights, over the resource (Benkler, 2003). All Commons have a material, a social and a regulatory dimension (Helfrich, 2009). The material dimension refers to the resource itself, the social to its user community, and the regulatory to the norms and rules that govern the use of the resource.

4 Seed and Variety Commons

Seed and Variety Commons (SVC) refers to a Commons-orientation in plant breeding, seed production and usage of seeds and varieties. To provide a well-grounded definition, a differentiation between seeds and varieties is necessary. Seeds are the physical carrier of varieties, which encompass their genetic code. Seeds have become an economic good that can be physically traded, while varieties have come to be a cultural and legal good whose usage is regulated in most countries (Wirz et al., 2017). Since varieties are inherently connected to a physical seed that carries the specific genetic traits of the variety, the two cannot and should not be entirely thought apart. Nevertheless, for discussing SVC, it is useful to distinguish between them.

Seeds and varieties have been managed as Commons for centuries through structures of seed exchange and collective breeding efforts of farmers. Since seeds reproduce naturally and are therefore not per se a scarce good, the privatization of varieties was historically not an option. However, usage restrictions have been brought about by (international) property laws such as patents and variety protection laws (Tsioumani et al., 2015). (Reseeding) fees associated with these laws and breeding techniques that curtail the natural reproducibility of seeds, allow for the exclusion of users and limit the repetitive usage of seeds (Luby & Goldman, 2016). Through these developments, both seeds and varieties have been made exclusive and are not regarded as Commons anymore in most contexts in the Global North and increasingly in the Global South. Nevertheless, initiatives in the field of organic breeding have in recent years been engaging in the processes of 'commoning' (Linebaugh, 2008), thereby creating institutional structures that allow for a collective management of seeds and varieties.

Hence, the conceptualization of seed and varieties as Commons presents particular challenges, because they combine elements of Traditional Commons (i.e., breeding and seed production clearly center around a natural resource) with two distinct elements of New Commons : (1) The genetic code of varieties and the associated information can be understood as a specific knowledge resource, and thus, plant breeding that manifests in 'institutionalized community governance' (Frischmann et al., 2014) can be defined as a Knowledge Commons. However, it needs to be recognized that varieties are created by a combination of natural ecological processes of propagation and adaptation to environmental conditions, and intentional or unintentional involvement of human activities, so that they are not the pure result of a human innovation process. (2) An important 'entrypoint' (Hess, 2008) into SVC is the need to protect the (genetic) diversity of crop varieties, which is argued to be a Global Commons (Berkes, 2007; Mudiwa, 2002). Therefore, different theoretical perspectives and approaches from these three types of Commons (Traditional Commons, Knowledge Commons and Global Commons) have to be connected for a definition of SVC.

As shown above for seeds and varieties, exclusion has been socially constructed and has changed over time with varying social and technological developments (Danwitz et al., 2002). This means that restrictive institutions can be altered. As a consequence, normative judgements of what should be shared, based upon the relevance of a resource for society as a whole, becomes a decisive factor

(Helfrich, 2012). Commons then refers to the organizing principles that enable the sustainable joint management of a resource. If we accept that (1) Commons are by definition a social and institutional arrangement that is purposefully put in place for the long-term provision of a resource and that (2) it is a social and political question of what ought to be a Commons, then we do not need to consider the question whether seeds and varieties are Commons, but whether they ought to be Commons.

There are three main strands of normative arguments for a Commons-orientation in the seed sector: (1) The preservation of varieties as cultural goods; (2) the re-democratisation of seed systems; and (3) the reaching of the global Sustainable Development Goals, including food security and the preservation of agrobiodiversity.

Varieties have been gradually developed over thousands of years, through selective breeding by farmers. They are natural resources with a large degree of human influence and the results of collective efforts of many (Kotschi & Rapf, 2016; Kugbei, 2003). As such, they are cultural products woven through the social fabric of local communities and highly intertwined with cultural traditions and practices. They influence a wide array of aspects of social life ranging from local diets to landscape aesthetics. Consequently, they have been considered a common heritage of humankind, which has led to an ongoing debate about whether their privatization is justifiable on ethical grounds (Helfrich, 2012).

The second argument relates to the re-democratization of seeds systems. Continuously growing large-scale agrobusiness increasingly dominate the western plant breeding landscape. In 2011, only ten companies controlled 75% of the seed market (ETC-Group, 2013). With a number of fusions currently in process, by 2018, this number will likely have reduced to three (Hirtz & Moldenhauer, 2017). A Commons-orientation in the seed sector would allow for a less centralized governance of varieties, may lead to more democratic participation in their development and management, and thereby improve food sovereignty in both the Global South and the Global North.

The third set of reasons refers to the global Sustainable Development Goals. Since the 1940s, the agricultural sector has been following in a strategy of agricultural intensification, in order to ensure food security for the growing world population (IAASTD, 2009; Loos et al., 2014). Increases in yield have however come at the expense of ecological sustainability (Millennium Ecosystem Assessment, 2005; Rockström et al., 2015). Such production systems often demand increased input of synthetic nitrogen fertilizers, pesticide and large-scale monocultures (Almekinders et al., 2007; Matson et al., 1997; Tilman et al., 2002). Furthermore, a worldwide loss of genetic crop diversity can be observed (Mace et al., 2014; van de Wouw et al., 2010). At the same time, the relevance of crop diversity increases as adaptation demands in the light of climate change intensify (Petersen & Weigel, 2015). Commons-based seed systems provide a promising coordination approach in aligning seed-production with the international sustainability goals of agrobiodiversity and ecological sustainability.

It remains to be discussed what characterizes Commons-based seed systems. In the early phases of the project, it has become apparent, that SVC are highly context-specific. Commons-based systems in the Global North vary vastly from those in the Global South. While in the Global North, a focus lies on a Commons-orientation in the management of varieties, in the Global South, seeds themselves are frequently managed collectively through seed-exchange-systems or collective seed banks (Pautasso et al., 2013; Vernooy et al., 2014). Still, a conceptualization of SVC needs to consider that seeds and varieties are intimately linked, since seeds are the carrier material of varieties.

Previous academic studies have analysed a Commons orientation in variety breeding and seed production from an institutional perspective in the context of international agreements (Dedeurwaerdere, 2013; Frison, 2016; Six et al., 2015). Frison (2016) thereby explicitly refers to seed Commons in her work. In addition, a number of (case) studies consider the governance of informal seed system in the Global South. These include participatory breeding approaches (Chable et al., 2014; Desclaux & Nolot, 2014; Galiè, 2013; Wilbois & Wenzel, 2011) and seed exchange systems (Calvet-Mir et al., 2012; Pautasso et al., 2013). A number of recent publications from actors in the field of ecological breeding have also conceptualized seeds and varieties as Commons (Kotschi, 2016; Wirz et al., 2017; Zukunftsstiftung Landwirtschaft, 2013). Nevertheless, a conceptual and operational delineation of SVC has so far not been provided. Following a process of deliberation with the RightSeeds practical partners, the following aspects have been identified as central features of SVC. To account for the different manifestations of a Commons-orientation in the seed sector, the defining characteristics of Seed and Variety Commons are kept broad on purpose.

Collective Ownership and Protection Mechanisms

Collective ownership is assumed over varieties. Property rights are not hold by individuals or profit-oriented organisations and no patents or other variety protection is claimed. Instead, varieties are registered to non-commercial organizations (see e.g. Kultursaat e.V., 2017) or fall under open-source licences or pledges. These legal or self-imposed protection mechanisms prevent the future appropriation of varieties as private property (Kotschi & Kaiser, 2012; Kotschi & Rapf, 2016), as any new user enjoys the same rights as previous users. An example provides the recently developed licence from Open Source Seeds. The licence is a material-transfer agreement that confers usage rights together with the material object, the seed. When the material is transferred, a contract is concluded that ensures the mutual, reciprocal rights and duties associated with the material in question, as well as all future developments to that material, in perpetuity. While the legal grounds of the licence refer to the protection of seeds, it implicitly also pertains to the genetic information contained within the given material and therewith effectively protects varieties (Kotschi & Rapf, 2016).

Breeding of Reproducible Seeds and Sharing of Knowledge

Breeding is a central task of society to ensure the long-term preservation and development of agrobiodiversity. To ensure seeds' and varieties' long-term societal value for cultivation and breeding, only breeding techniques that result in open-pollinated varieties are used. Techniques that result in seeds that are sterile and not self-reproducing are not utilized. Knowledge on cultivation techniques, as well as on growing conditions and specifications of varieties are fully disclosed and unconditionally shared publicly. Cultivation and breeding processes are often also associated with high ecological standards. While there are deviating opinions on whether high ecological standards are a prerequisite for a Commons-based plant breeding, in practice a Commons-orientation in plant breeding and seed production is almost always connected to organic breeding and cultivation practices.

Effective Polycentric Institutions for Collective Management

Collective responsibility ensures the provision, development and preservation of varieties. As noted by Ostrom (1990), institutional arrangements, including norms and rules, are required for the sustainable management of Commons. SVC are characterized by polycentric governance arrangements that allow for the decentral management of seeds as a collective resource (vgl. Aligica & Tarko, 2012; Andersson & E. Ostrom, 2008; Berardo & Lubell, 2016; E. Ostrom, 2010a; Thiel, 2017). Polycentric governance refers to the presence of “many centres of decision making which are formally independent from each other [but are] […] capable of making mutual adjustments for ordering relationships with one another” (V. Ostrom, 1972, p. 1). SVC are characterized by decentralized decision-making structures, implemented for instance through participatory breeding approaches, that are manifested in the organisational structures of initiatives. As autonomous decision-making centres which operate under collectively agreed upon rules (e.g. by means of open-source licences), breeding initiatives establish open innovation systems. From a practical point of view, the question arises as how to finance breeding in an organizational arrangement that keeps varieties open and cost-freely accessible to all. With a Commons-orientation, income generation through fees and royalties associated with protected varieties is not an option. Consequently, diverse financing strategies are needed to ensure the long-term provision of collective breeding activities. Alternative income sources such as public funding or new financing mechanism along the value chain (e.g. ‘variety development contributions’ that are negotiated between breeders, seed producers and farmers) could provide possible funding mechanisms for SVC. In the context of seed exchange networks that operate outside formal markets, financial concerns are less prominent.

These characteristics are not to be understood as a conclusive definition of SVC. Rather, they provide a starting point for the RightSeeds research project and will likely continue to evolve throughout the research process. Specific conceptualization of SVC will be highly context dependent and require differentiated definitions that are adapted to the specific socio-economic arrangements of the seed system or the initiative of interest.

***Seed and Variety Commons* (SVC) in the context of the *RightSeeds* project**

SVC refer to common ownership and forms of collective management in plant breeding, seed production and the use of seeds and varieties. In the Global North, SVC are currently implemented in the context of Commons-based variety breeding, while in the Global South, seeds themselves are often governed as community resources. SVC have the following characteristics:

Collective ownership and protection mechanisms: Private ownership rights to seeds and varieties (variety protection and patent rights) are replaced by collective ownership forms. To ensure the preservation and further use as a common property, varieties are registered via non-profit organizations or open-source licenses.

Breeding of reproducible seed and sharing of knowledge: Breeding is a central social task for the long-term preservation and development of crop diversity. Only breeding techniques that result in reproducible varieties are used. Knowledge on breeding techniques and variety characteristics is shared freely.

Effective polycentric institutions for collective management: Polycentric governance arrangements allow for the decentral management of seeds as a collective resource. As autonomous decision centres which operate under collectively agreed upon rules, breeding initiatives create open innovation systems.

5 Conclusion

For the project RightSeeds, the concept of Seed and Variety Commons presented in this discussion paper serves as the integrative theoretical framework to transcend several disciplines and practice areas. The reflection on the key terms and concepts connected to SVC (see chap. 3), their evolutionary history and their practical relevance has shown that they have implications that reach beyond terminological clarifications. The discussion of these key concepts has helped to highlight and clarify relations among concepts, but also points to interdependencies that remain vague and require further exploration. An overview of the relations, conceptual linkages and future research interests in given in figure 5.

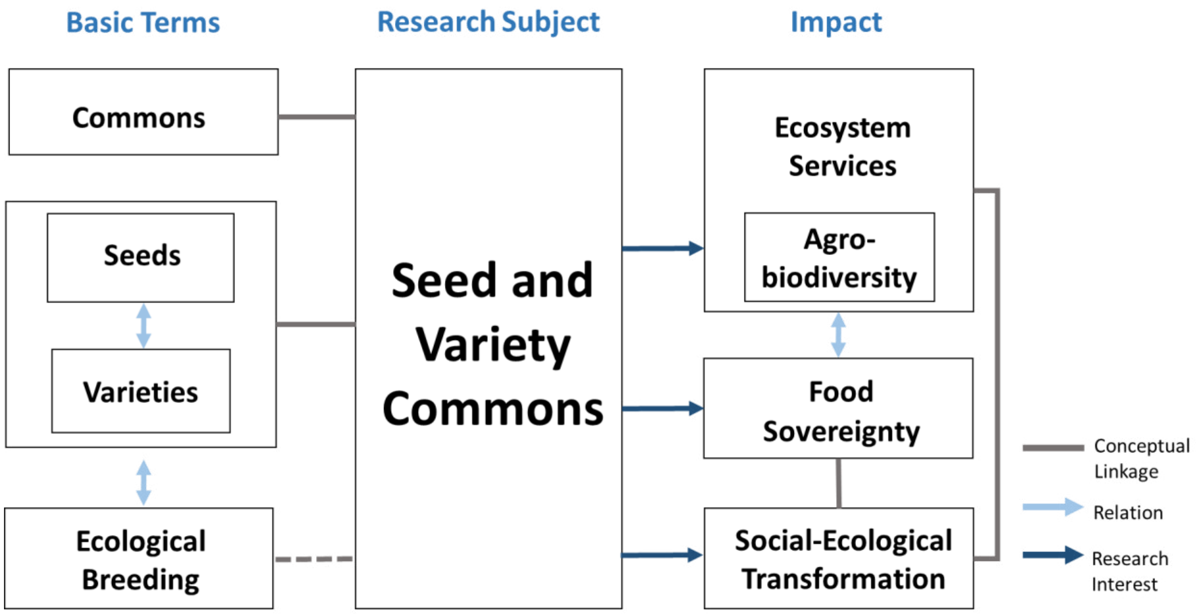

Figure 4: *Relations between the key concepts of RightSeeds (own figure).*

Commons, seeds and varieties, and ecological breeding have been identified as the basic terms that provide the foundation for the integrative concept of Seed and Variety Commons. Seeds are the carrier of the genetic material and information of varieties and are consequently needed for the propagation and further development (breeding) of varieties. Demands towards varieties impact how breeding is pursued. In turn, the design of breeding determines which (kinds of) varieties are developed. This relation between seeds, varieties and breeding is reflected in the proposed conceptualization of Seed and Variety Commons. SVC combine elements of Traditional Commons (seed as a physical natural resource), Knowledge Commons (the genetic code of varieties and the associated information) and Global Commons (varieties as expressions and carriers of biodiversity). These three layers are interconnected since a large part of the information about the respective variety is embedded as genetic code in each seed. This excludes knowledge regarding cultivation practices, propagation and use, which needs to be shared more directly. From a more practical perspective, organic breeding is often connected to Commons approaches in seed production and variety breeding in Germany. While ecological standards are not a prerequisite for a SVC, there are conceptual overlaps, since organic breeding rejects the use of methods that can limit the reproducibility of seeds, which is an important characteristic of SVC.

As described above, based on a proposal by the scientific project team, the integrative frame of SVC, being the central research subject of the project, was discussed, refined and adapted conjointly with the RightSeeds project's practical partners in the context of a workshop. The concept of SVC reflects the current state of the Commons debate and is agreed on by all project partners from practice and science. In this way, a convergence towards a common understanding of the research subject was successful. Despite the success of the transdisciplinary work within RightSeeds in identifying common features of SVC, many challenges remain. One issue regards the size and potential limits of the user community of SVC. While there is a general desire to keep seeds and varieties freely accessible by renouncing private property rights such as patents and licenses, from a practical perspective this raises the question of how to then still ensure sufficient financing and recognition of the breeding efforts, as well as a responsible use of seeds and varieties. This illustrates the need to examine the practical and organizational design of SVC more closely. The integrative concept of SVC will thus be applied to the specific forms of organization and working contexts of the practical partners and its pertinence will be reflected and further developed as the RightSeeds project progresses.

Besides the conceptualization of SVC, this paper has also helped to clarify the state of debate and relations among normative concepts such as agrobiodiversity, food sovereignty, or the more comprehensive target of a social-ecological transformation. The impact of SVC to these normative goals will be a central research interest within RightSeeds.

The general positive contribution of a high level of agrobiodiversity towards increased ecosystem services has been explored in detail above. Agrobiodiversity also tends to have a positive effect on food sovereignty, especially with regard to the diversity in cultivated varieties allowing for a better adaptation to marginal cultivation conditions or changing environmental and climate conditions (Christinck & Tvedt, 2015). In turn, the decisive role of humans and their culture and knowledge in the conservation of agrobiodiversity has been recognized (Cromwell, 1999). Food sovereignty strengthens this connection, because individuals and communities with the right to determine their own food systems are more likely to cultivate, preserve and further develop diverse, local varieties that are well adapted to their specific context conditions (Altieri & Toledo, 2011; Chappell et al., 2013; Claeys & Lambek, 2014).

A central goal of the RightSeeds project is to investigate the potential of Commons-based seed systems to drive a social-ecological transformation of plant cultivation. In this working paper, a first draft definition for a social-ecological transformation for the case of plant cultivation is proposed. Food sovereignty and improved levels of agrobiodiversity have been identified as central components of a social-ecological transformation. Other aspects include a process-orientation that acknowledges various forms of knowledge and aims at empowering marginalized actors. Nevertheless, the definition remains vague and requires the development of concrete principles that can be used to evaluate the potential contribution of SVC to a social-ecological transformation in plant cultivation.

A collective and polycentric management (being a central element of SVC) offers potential for the integration of different forms of knowledge, such as more traditional and local perspectives, and the development of (breeding and seed production) approaches adequate for each specific context. From a conceptual perspective, SVC are very likely to contribute to food sovereignty, in particular seed sovereignty, because they aim at improving the access to seeds by refraining from restrictive private property rights and methods limiting the reproducibility of seeds. They also encourage the sharing of knowledge regarding varieties and breeding as well as a decentral (self-)management of seeds and varieties. A positive contribution of SVC to agrobiodiversity is likely, because a better access to seeds and varieties and a polycentric management approach could encourage new and more diverse breeding efforts, also on-farm. The focus of breeding in SVC tends to be on various, regionally well-adapted varieties rather than high-yield varieties for a large outlet market. Consequently, SVC seem to have a high overall potential of contributing to a social-ecological transformation.

The generated hypotheses need to be addressed in more detail both theoretically and empirically. This paper has helped to generate more specific research questions that will guide the future transdisciplinary work of the project RightSeeds:

- What constitutes SVC and their institutional embedding in the Global South and the Global North?
- What does a social-ecological transformation entail in plant cultivation?
- Which methods and theoretical concepts can be drawn on to measure the contribution of SVC to a social-ecological transformation?
- In which way are organizational forms of breeding and seed production connected to social-ecological impacts in plant cultivation? How can positive social-ecological effects of SVC be augmented?

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