Appendix 2: Codebook

This codebook compiles the attributes assigned to text sections in the primary case studies. Not all of these attributes are analysed in the paper because some yielded too little information for meaningful configurations. The codes with more digits denote sub-variables of codes with fewer digits, e.g. 1.2.1 is a sub-variable of 1.2.

1. Context conditions

Context conditions include a variety of components that are important for describing a specific case. They refer to conditions of the researcher, the sustainability problem that the project is addressing, the degree of wickedness characterizing the case, actors and their context, the institutional background, the knowledge that is missing in the case, or power relations. In addition, we coded so-called situation changers that refer to unforeseen events with a high impact on the project.

1.1 Research context

This code refers to the researchers' contacts in the field. They are new if researchers get to know the societal actors at the start of the project, or they are firmly established if the researchers know the societal actors from previous projects or other contexts.

An example for a firmly established contact would be a follow-up project of a previous research project with the same societal actors.

1.2 Sustainability problem

This code describes problems for sustainability addressed in the project. They concern different dimensions such as resources and environment, the socio-economic environment, or governance questions.

1.2.1 Resources and environment

In resources and environment, we distinguish between competition, degradation, pollution and conflict. A competition problem takes places when different actors compete for the same scarce resource. This can lead to different situations such as advantages for more powerful resource users or degrading user habits due to overuse. An example for this situation is competition for water use in water scarce areas.

Degradation is coded when resources are overused. Examples are overgrazing of pasture land or increasing pest infestations due to unsustainable agricultural practices.

Pollution problems are coded when water quality is concerned. These problems concern too many nutrients from fertilizers or run-off from pesticides.

Conflicts between different resource users over resources are extreme cases of resource and environment problems. They range from low level (e.g., local disputes) to high-level conflicts (i.e., violence and armed conflict).

1.2.2 Socio-economic

Socio-economic sustainability problems concern societal issues and their economic implications. This code covers situations where the structure of a society or the structure of the economic system cause the problem. We distinguish between viability, markets, population pressure, poverty, gender and dependency.

Economic viability concerns unsustainable economic settings such as businesses or other settings where the actors slowly degrade their assets base. Examples are declining margins and regular crop losses in specific agricultural sectors.

Markets problems refer to non- or ill-functioning markets. Examples are lacking markets to sell the products or poor market access due to remote locations.

Population pressure is coded when populations grow fast or when populations are large. These problems are often related to degradation problems.

Poverty is coded when populations are lacking the necessary means to sustain their daily lives or to make necessary investments. Examples include poverty after a job loss or insufficient margins for own produce.

Gender problems cover unequal access to land or other resources or decreasing crop production due to gender inequalities. Examples include women loosing their jobs first in economic crisis situations or women having unequal access to land.

Dependency problems are coded when people are dependent on outside support, which limits their own choices substantially. An example is the dependency on relief aid of international donors.

1.2.3 Governance

Governance problems involve the way in which resources or the society are governed. We distinguish between access, distribution and mismanagement.

Access is coded when people lack access to resources, social security systems, or other state services.

Distribution is coded when existing policies lead to uneven distribution of resources or poor infrastructure in certain areas.

Mismanagement problems are coded where the management of a system is inefficient and unnecessary losses occur. Examples are regulations that lead to low quality products, inadequate monitoring activities, or decaying infrastructure.

1.3 Degree of wickedness

Wicked problems are problems that cannot be solved (Rittel and Webber, 1973), because of complex interrelations where solving one aspect leads to problems elsewhere; connections over space and time render the outcome uncertain; and a high degree of normativity with conflicting values. We address these different dimensions of wicked problems through the sub-codes complexity (low vs. high), uncertainty (low vs. high), and conflicting values (consensus vs. conflict). Examples include problems within one sector vs. overlapping of different sectors and institutions (complexity); open unclear processes (uncertainty); or strong polarisation of actors' opinions on what is the right approach to address a specific problem (conflicting values).

1.5 Missing knowledge

In participatory research approaches, researchers often refer to different types of knowledge (CASS and ProClim, 1997), which include systems knowledge (how does a system function), target knowledge (what is a desirable state of a system), and transformation knowledge (how do we get to this desirable state). For an assessment of different participatory approaches, we code missing knowledge related to these knowledge types in the case studies.

The codes cover situations where the functioning of a system is investigated (system knowledge); where a common goal or vision is sought (target knowledge); or a clear strategy for getting from one state to the other is necessary (transformation knowledge). Examples include investigation of climate change effects on farmers (system knowledge), the definition of best management practices (target knowledge), or how agricultural innovation networks can achieve more concerted actions (transformation knowledge).

1.5 Actors

This code informs about the involved actor groups, networks, familiarity, motivation and capacity of the involved actors, and the power constellation. The sub-code situation changers includes important events that change the course of the whole project but do not necessarily fit in one of the other categories.

1.5.1 Network

This sub-code informs about the way in which actors were connected before the project started. Familiar actors know each other but without having worked together before. New actors do not know each other at the start of the project and need to build all connections first. Well-established groups know each other from previous projects where they worked together before and trust is already built.

1.5.2 Setting

The research setting refers to the group constellations. Multi-actor groups bring together actors from different sectors and backgrounds. Single-actor groups bring together people from the same actor, organisation or background such as farmers, extension workers, government administration, soil scientists and seed producers.

1.5.3 Level

The level of actors includes the sub-codes sector, organisation or individuals.

Examples include different actors in the oil palm seedling supply system (sector); a group of civil servants from a Dutch ministry (organisational); or different actors from a community such as landowners, landless, men, women, children (individuals).

1.5.4 Motivation

Motivation informs about who initiated a project. Bottom-up initiatives are initiated by societal actors, top-down initiatives are launched by governmental actors or agencies, and research initiatives are started by researchers.

Examples include communities that address researchers to help them promoting their agricultural products (bottom-up); action plans to fight pest infestations in whole countries (top-down); or the desire to test the effectiveness of new management models (research).

1.5.5 Actor capacity

Capacity defines the availability of time and social competence among actors. We distinguish between knowledge, lack of knowledge, time, lack of time, social competence, lack of social competence.

Examples include important knowledge contribution by indigenous groups or the lack of adequate scientific knowledge (knowledge); the tight schedule of farmers during crop season (lack of time); behaviour that excludes certain actors from a group (lack of social competence).

1.5.6 Power

We refer to Avelino and Wittmayer (2016) and their classification for coding power constellations. This includes one-sided dependence (A depends on B but B does not depend on A => B has power over A), mutual dependence (A depends on B and B depends on A => A and B have power over each other), independence (A and B do not depend on each other => A and B have no power over each other), cooperation (A exercises more power than B, but A and B have similar, collective goals), competition (A exercises more power than B, while A and B have mutually exclusive goals), and co-existence (A exercises more power than B, A and B have independent co-existent goals).

There were hardly any codings for this code.

2. Sustainability impact goal

The sustainability goal varies from case to case and takes different forms depending on what the aims of a project are. Often, projects have different interlinked sustainability goals. The categorisation of sustainability impact goals refers to Mitchells outcome space framework ((Mitchell et al., 2015).

2.1 Knowledge products

According to Mitchell et al. (2015), knowledge products contribute to knowledge stocks and flows, hence they are specific products that build parts of a knowledge system. We distinguish between decision-making tools, knowledge databases, action plans, scientific publications and non-academic publications.

2.1.1 Decision-making tool

Decision-making tools are support tools that help actors to take decisions in specific situations. An example is a whole farm simulation tool to tailor dairy farm adaptive management strategies for different climate conditions to decrease environmental impacts.

2.1.2 Knowledge database

Knowledge databases collect information within a specific thematic or methodological area.

2.1.3 Action plans

Action plans are strategies that explain how specific goals will be achieved within a certain timespan. An example is a project with a group of farmers to identify and develop potential solutions to soil productivity problems.

2.1.4 Scientific publications

Publications in peer-reviewed scientific journals.

2.1.5 Non-academic publications

Publications in non-scientific knowledge dissemination such as reports, newspaper articles, television programmes, etc.

2.2 Learning

The sub-code learning includes everything that refers to learning in the broad sense such as individual or group learning. We distinguish between development of ownership, new knowledge, networking, reflection on learning, trust building, self-confidence, capacity building and communicating best practices.

2.2.1 Development of ownership

Through the participation in a project, the actors develop a feeling of being part of the project and having ownership of the project's impact. Examples include cases where the involved actors take over responsibility of the project's impact and carry on with it or further develop it after the project ends.

2.2.2 New knowledge

Different types of new knowledge on different topics are produced during a project.

2.2.3 Networking

This includes activities that intend to build new connections or establish relationships between the projects and other actors. An example is to link networks from previous projects to the actors in a new project.

2.2.4 Reflection on learning

Reflection on learning includes activities and exercises within a group to reflect on the performance of the group and to think about improvements in the groups processes. An example is the gathering of organic cooperatives and certifiers to think about the role, they can play in building resilience to climate change.

2.2.5 Trust building

Trust building includes activities that bring the different actors closer together and make them develop trust towards each other.

2.2.6 Self-confidence

This sub-code includes processes that strengthen actors' confidence that they are able to carry out or have the capacity to fulfil certain activities.

2.2.7 Capacity building

This includes processes to improve the capacity of actors in order to do their work. Examples are familiarising actors with processes and procedures, support actors in determining their preferences, or professionalising a problem solving approach and promote it to other actors.

2.2.8 Communicating best practices

This includes showing and communicating best management practices to a broader community. An example is the communication of recommendations for a more sustainable milk value chain.

2.3 Real world transformations

The categories in real world transformations refer to the classification by Gibson et al. (2005). They seem more suitable for our analysis than more classical distinctions between social, ecological and economic criteria because sustainability problems usually involve more than one of these three areas and are difficult to separate. Gibson's classification rather defines problem areas.

2.3.1 Social-ecological integrity

Social-ecological integrity codes goals that preserve the interrelations of social and biophysical systems and therefore, a key component of human wellbeing. It not only involves human impacts on the environment but also considers all the components of these systems such as social, ecological,

economic, political as well as cultural aspects. An example are best practices for sustainable banana production that do not come with restricting regulations or administrative burdens.

2.3.2 Enhanced livelihoods

Enhanced livelihoods address the needs of people and communities. It entails different levels of needs depending on societies and cultures. Gibson et al. (2005) refer to sufficiency and opportunity when defining enhanced livelihoods, and distinguish between things that are necessary for survival and things that are necessary to live a fulfilled and meaningful life. An example is better marketing of rooibos production coupled with community-based tourism, which provides new attractive jobs and better incomes for the community.

2.3.3 Intra- and intergeneration equity

Intra- and intergenerational equity entails in the first place material equity. However, this does not suffice as material equity is closely related to political power and the possibility to participate in decision-making processes. In addition, the context in which people are born often influence their development in life and lead to a certain path-dependency for their children as well. Besides path-dependency in people's lives, the question of sufficiency and opportunity extends into the future for generations to come. Negotiating needs and values for future generations is an intractable task and yet needs to be included in the discussion on sustainability.

2.3.4 Resource maintenance and efficiency

Resource maintenance and efficiency is an important requirement for sustainable development because it leads a way to a more careful use of resources. Although it will not be sufficient for solving sustainability problems in general, it must play an important part in the transformation from current to more sustainable lifestyles. An example is high crop production while decreasing water pollution and minimising production costs.

2.3.5 Social-ecological stewardship and democratic governance

Social-ecological stewardship and democratic governance combines four different dimensions which often tend to be analysed in isolation. These include government, markets, custom and choice. In sustainable development, however, it is most often not possible to separate them. The requirement is based on transparency and participatory processes. An example is a sustainable community organising effort around natural resource management based on broad-based participation, cost sharing, and co-management.

2.3.6 Precaution and adaptation

Risk, uncertainty and complexity in sustainability problems require precaution and adaptation in their search for solutions because it will never be possible to anticipate everything that will happen. This sub-code involves efforts to deal with unexpected consequences and effects that evolve with the solutions. Learning should be an inherent component thereof in order to make adaptation during processes possible. An example is the selecting, testing, and upscaling sustainable land management strategies to mitigate desertification.

3. Participatory approach and methods

This part describes what research approaches and methods are chosen, how different actors are involved in the process, and what roles they play.

3.1 Participant roles

Researchers and societal actors can take different roles in participatory research. We refer to work by Pielke (2014) for defining these sub-codes.

3.1.1 Societal actors

For the roles of societal actors, we distinguish between facilitating a participatory process, actively engaging in a process as knowledge producer, taking a more observing part as stakeholder, or being an expert who can give detailed input on a specific topic. These different roles also imply different understandings of the actors' contributions.

3.1.2 Scientific actors

The same is valid for scientific actors. Their contributions and responsibilities change depending on their roles as facilitators who organise reflexion processes, knowledge producers (which is the classical role of researchers), or experts who are invited to give their expertise in specific moments.

3.2 Research process

Our definition of research phases in participatory research are based on the work by Lang et al (2012). They introduce a set of design principles for an ideal transdisciplinary research process and differentiate three phases in the process, namely the framing of problems and the establishment of a research team, collaborative research and the co-production of knowledge, and the integration of new knowledge into societal and scientific practice.

3.2.1 Research phase 1: problem framing and research team

Activities in this sub-code include building a collaborative team, the joint problem identification and definition, jointly defining objectives and questions, assigning and supporting roles for actors, and agreeing on methodology for co-production and integration.

Examples include recruiting an interdisciplinary team to carry out different aspects of a project, the discussion of farmers' most relevant problems, the definition of objectives for a joint vision in 2025, establishing a facilitation team to organise exchange visits, or discussing and defining the individual steps and procedures of a project.

3.2.2 Research phase 2: collaborative research and co-production of knowledge

Activities within this sub-code include the integration of different methods, the adjustment of methods when necessary, the integration of different types of knowledge, and the mitigation of conflict when it occurs.

Examples include methods to integrate different learning episodes over time and space, the commitment to set an open agenda flexible for changes, the consideration of knowledge from different actors in the joint knowledge production, or the mitigation between conflicting groups within a project.

3.2.3 Research phase 3: integrating new knowledge into science and societal practice

This sub-code includes the integration of knowledge into science, the integration of knowledge into societal practice, generating targeted products, and evaluating impact.

Examples include the adaptation of scientific documentation, which includes the results from societal knowledge, the testing of project results on the own farm, to make agroecological management alternatives visible through local food markets or radio programmes, or to enquire actor's experiences in different study sites.

3.2.4 Intensity of actor interaction

This sub-code includes intensities of actor interactions, i.e. information, consultation and co-production in all three research phases. We code different activities that either inform actors about the project, its achievements or planned activities; consult actors about their wishes, concerns, expectations or preferences; or co-produce new knowledge in a joint effort where all involved actors contribute to the process with knowledge, expertise, time, etc.

Examples include first oral presentations and handing out of flyers, semi-structured interviews or questionnaires, or intense participatory knowledge production workshops with different actors.

4. Impact

The impact categories learning, knowledge products and real world transformations correspond to the sustainability impact goals.

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