HOLISTIC RESOURCE MANAGEMENT FOR
CLIMATE RESILIENCE OF FARMING

Theoretical Description of the ClimateFarming Cycle

ClimateFarming

2022-1-DE02-KA220-VET-000090163

Provided by: TRIEBWERK,
kontakt@triebwerk-landwirtschaft.de
TRIEBWERK - Regenerative Land- und Agroforstwirtschaft UG
Im Rothenbach 49, D-37290 Meißner
https://www.triebwerk-landwirtschaft.de/

Date: July 2023, last update November 2023

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Co-funded by the European Union

Contents

Co-funded by the European Union

The ClimateFarming Cycle: SUMMARY

Aim: Address the challenges of climate change adaptation at farm level.

Target group: Experts and consultants from the agricultural sector. Possible for farmers that are able to invest some hours and can get support from a consultant if needed.

Background: Combining different methodological approaches, including "Decision-making Under Deep Uncertainty" (DMDU) and "Strategic Farm Management" with findings from practical projects. More information provided in the CF Trainer Handbook

Consists of **five modular process steps**:

1. farm survey
2. farm vulnerability analysis
3. adaptation measures
4. farm climate strategy
5. monitoring and implementation

The individual steps can be used independently of each other and adapted to the individual farm conditions.

The main product is a farm-specific climate strategy with a strategy-specific monitoring system.

Monitoring is a core element of the process to ensure regular evaluation of the success of adaptation measures, to identify necessary changes in measures and strategies and to stimulate learning processes.

Co-funded by
the European Union

Introduction

Agriculture is affected by climate change like hardly any other sector. This poses new and unknown challenges for agriculture as a whole, but also for each individual farm. In order for farmers to be able to identify, assess and manage these complex challenges, a holistic approach is required. This approach must take into account the specificities of the individual farm and integrate the regionally specific impacts of climate change. Furthermore, it must support the use of synergies between different protection and adaptation measures and enable proactive, far-sighted farm management. In addition, the approach must incorporate the risks resulting from uncertainties (associated with climate change) into the planning process and minimise them as far as possible. However, some risks cannot be foreseen or minimised. Therefore, farm-level strategies need to be resilient and flexible so that they can be easily adapted and modified in case of unforeseen changes.

The ClimateFarming Cycle is a Decision-Support-Tool[1] in the form of a modular planning framework divided into five steps. The basis is the *ClimateFarming Handout*, in which the different steps of the ClimateFarming are compiled in a practice oriented manner. This includes To-Do's, templates and info-sheets with which the individual steps can be conducted. The handout, and the ClimateFarming Cycle as a whole, is intended to support consultants in developing climate strategies for individual farms together with farmers.

The aim of the ClimateFarming Cycle is to enable advisors, experts and farmers to act proactively despite the dynamic and uncertain course of climate change. The focus is not on individual measures and their implementation. Instead, the ClimateFarming Cycle is intended to direct the actors' attention to the interaction of short-, medium- and long-term measures in the field of climate protection and climate adaptation and help them to fit these measures to individual farm objectives and conditions. In doing so, the risks of misalignment are minimised, synergies between different measures are used and possible conflicts of objectives are actively dealt with. The ClimateFarming Cycle serves as a template for how different methods from the field of farm planning and adaptation management can be used at the farm level. Since the focus is on the individual farm, the methods used in the ClimateFarming process should always be designed according to the individual farm. The modular structure of the ClimateFarming Cycle helps here, making it possible to apply individual steps independently to best fit the use case.

Example for the modular structure of the ClimateFarming Cycle: The five steps of the ClimateFarming Cycle can be applied independently of each other. For example, if a farm does not have enough time to go through all five steps, only a comprehensive farm analysis (step 1 and step 2) can be carried out, followed by a collection of adaptation measures (step 3). This does not result in a climate strategy for the farm in question, but it gives the farm managers an overview of possible adaptation measures for their farm and enables them to make better decisions for farm development.

It is up to the users to decide which parts of the ClimateFarming Cycle and the different methods are used or how they are adapted to individual operations. However, this should always be done in a well-

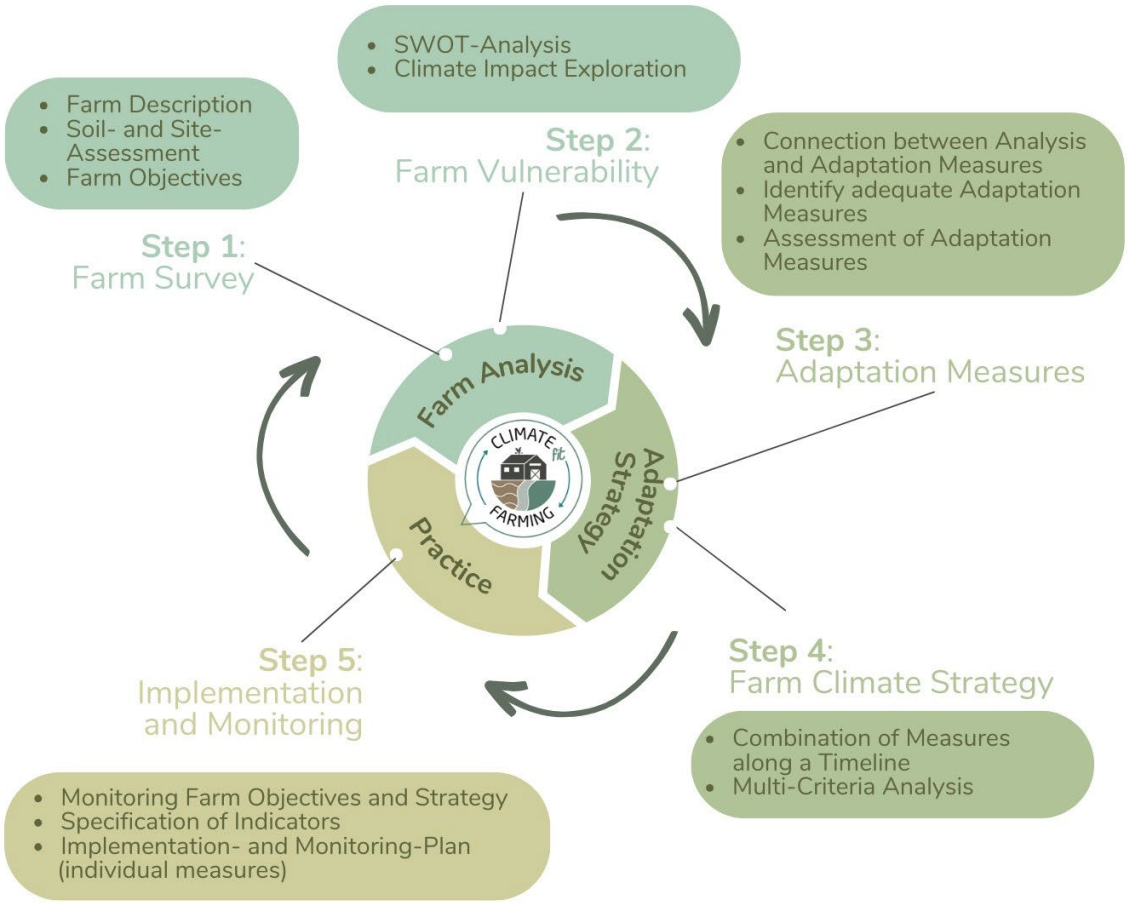
[1] Decision-Support: Collection of processes which serve the purpose to generate and use information relevant for decision-making (US National Research Council, 2009). Three aspects are emphasized by Marchau et al. (2019):
(1) The way how knowledge is integrated into decision-making processes is as relevant as the knowledge or information itself
(2) The co-production of knowledge by the provider of information and the user of information
(3) The decision-making processes must be designed in a way that the users (decision-makers) are able to learn

considered manner and, if in doubt, in consultation with experts, so that the effectiveness of the ClimateFarming Cycle is maintained. Furthermore, the ClimateFarming Cycle is also a dynamic tool and is constantly being further developed on the basis of new practical and scientific findings. Accordingly, the present version only shows the current state of development of the ClimateFarming Cycle.

Due to the high - but necessary - complexity of the ClimateFarming Cycle and the interaction between agriculture and climate change, this chapter is primarily aimed at agricultural consultants. Although the methods and planning process are described in a generally understandable way, the practical implementation on most farms will not be possible without external support due to the time required. Nevertheless, all practitioners are invited to use the ClimateFarming Cycle themselves to develop a farm-specific farm climate strategy or to adopt individual steps and insights from this guide in their own farm management.

Theoretical Description of the ClimateFarming Cycle

IN A NUTSHELL
The five steps of the ClimateFarming Cycle are explained below. Where reference is made to the **ClimateFarming-Consultant**, this is the person who goes through the process with the farm members and adapts the steps to the individual farm. As this is usually not a member of the farm but an external professional (an external consultant), it is divided into ClimateFarming-Consultant and **t**he **Farm Members.** The farm members are all involved parties at the farm. This includes the farm manager(s), all farm workers and possibly also family members or others who are involved in decision making or may be affected by new decisions.



Overview ClimateFarming Cycle

Step 1: Farm Survey

IN A NUTSHELL

- Guiding question(s): What is the status quo on your farm? Are you already implementing or planning to implement specific adaptation measures? What are the farm objectives?
- Step 1 sets the stage and the framework for the following application of the ClimateFarming Cycle. This framework determines the scope, and (time) resources needed and consequently the depth of the application. The ClimateFarming Consultant gets acquainted with the farm and its characteristics. This is their foundation to plan and conduct the application of the ClimateFarming Cycle. Additionally, the farm members are required to get a clear idea of what they want to achieve with their farm and their activities. They formulate Farm Objectives, which will be the guide for all that follows. These farm objectives will be the foundation for exploring vulnerabilities, collecting adaptation measures and ultimately the bar to measure success or failure of an adaptation strategy.
- Step 1 entails the following tasks:

- Introduction to the ClimateFarming-Project, the ClimateFarming-Cycle and the goals of the ClimateFarming consultation; alignment with expectations of farm members
- Deciding of the scope of the ClimateFarming Cycle and its implementation (e.g. going through the complete cycle or only using individual steps)
- Establish a status quo of the farm using the Farm Survey and the Site- and Soil-Analysis
  - The Farm Survey is a questionnaire which will be filled in by the farm members and the consultants to provide basic information concerning the farm, incl. implemented or planned adaptation measures
  - The Farm Survey also entails a step-by-step guide for how a field-specific analysis should be conducted, called the Site- and Soil-Analysis
- The farm members formulate farm objectives. These objectives should not only comprise economic objectives, but also other aspirations (e.g. ecological, social or other). Important is to formulate guiding objectives (qualitative goals) and measurable objectives (quantitative) if possible

The purpose of this step is to describe the farm and its characteristics and to formulate farm-specific objectives. This knowledge is important for the vulnerability analysis in step 2 and the identification of farm-specific adaptation measures in step 3. The farm objectives serve as indicators to evaluate the success or failure of the farm climate strategy.

Recording and describing the current situation of the farm is the basis for all further steps. This includes information on climate, soil, land, production branches and methods as well as other important information, summarised in the Farm Survey. An important part of the farm description is to determine the extent to which climate adaptation measures have already been implemented or planned. This provides a basis on which future measures can be built.

If a CO2-footprint is planned, it is relevant to define the methods as well as system boundaries for the assessment, so that these are consistent when evaluating measures and strategies. In addition to the farm description, the soil and site analysis of the Farm Survey serves to identify problems specific to different farm sites and fields and to subsequently formulate solutions (in later steps). Read more in the Farm Survey.

Objective Formulation

In classical business management, the goals of entrepreneurial action usually include profit maximisation with certain restrictions resulting from the values and norms of the business managers. The ClimateFarming Cycle recommends moving away from this type of goal formulation and instead formulating goals on the basis of so-called critical results. In economic terms, this means defining the minimum profit necessary rather than the desired maximum profit. Example A is supposed to illustrate the concept in a practical manner.

This approach of “critical results” is helpful when different adaptation measures or development paths for a farm are possible and the farm members must decide between different options. The advantage of using critical results is that it provides guidance on how to choose between different options. Instead of considering which option yields the highest (financial) benefit, the farm members are required to check whether an option is potentially able to satisfy the farm objectives (critical results) and then examine how risky or uncertain the success of an option is. Example B is supposed to illustrate the concept in a practical manner.

Example A: A resilient farmer:
Arable farmer A pursues the goal of profit maximisation and wants to earn "as much money as possible" from the farm. That is why the farm only grows high-yielding varieties. This guarantees very high yields in optimal years with balanced weather, and low disease and pest pressure. However, in years that do not meet these optimal conditions, the farm suffers high losses. Arable farmer B has set “critical results” that the farm must meet in order to function. One of these results is to achieve a five-year average output of at least 80,000€ net margin. In order to achieve this critical result even in bad years, she grows different varieties. This includes drought-tolerant varieties. These varieties do not produce as high yields as farmer A's varieties in optimal years, but losses in dry, non-optimal years are lower and the farm is able to achieve critical results.

Example B: How the approach of “critical results” influences deciding between options:
The agricultural activities of the example farm must generate a surplus of 60,000€ per year in order to pay the farm managers and build up reserves. In order to achieve this goal, the farm is looking into setting up an additional production branch. There are two alternatives: Branch A and Branch B. If Branch A is implemented, the annual profit could increase to 65,000€ - with Branch B up to 80,000€. However, when analysing the two alternatives, it becomes clear that the potentially higher profit of Branch B is subject to much greater uncertainties and risks. In terms of resilience and achieving the critical results, the less vulnerable Branch A is favoured, despite lower profit prospects (under optimal conditions).

For agricultural practice, the reduction of yield variability by giving up optimal yields is basically not new and part of strategic farm management. However, it makes sense to be aware of these decisions and also to formulate corresponding qualitative and quantitative objectives. The guiding question asks what results the farm activities need to achieve in order to be satisfactory for all farm members. The process of formulating farm objectives should be as inclusive as possible, including all farm members.

It is important to remember that many different objectives may be important to a farm and its members, including economic outcomes, ecological demands, social factors or other farm-specific

aspects. These goals may overlap, complement or conflict with each other. The goal must be to find the adaptation measures and strategies which perform the best across the various farm objectives.

Step 2: Farm Vulnerability Analysis

IN A NUTSHELL

- Guiding question(s): What are the strengths and weaknesses of our farm? What opportunities and threats can arise for our farm? What climate changes and impacts do we need to prepare for? Which are the most pressing vulnerabilities adaptation needs?

- Step 2 serves as a farm-specific vulnerability analysis for the potential threats and opportunities that may arise from climate change. This step combines the analysis of current vulnerabilities with the exploration of experienced or potential climate impacts on the farm. Like in all other steps, the value of its results is highly dependent on the participation of the farm members and a clear understanding of all participants concerning the goals, scope and methods of the farm vulnerability analysis. The insights developed in Step 2 (together with Step 1) are the basis for compiling farm- and/or field-specific adaptation measures (Step 3).

- Step 2 entails following tasks:
  - Plan the farm vulnerability analysis
  - Conduct a farm vulnerability analysis
    - Analyse the current vulnerability of a farm based on SWOT-Analysis: *Strengths, Weaknesses, Threats* and *Opportunities*
    - Collect past and recent climate impacts and explore which future climate impacts could be negative or beneficial for the farm
    - Connect the SWOT results and the exploration of climate impacts in order to prioritize certain farm aspects and/or climate impacts where adaptation is necessary (called *Adaptation Need*)
    - Analogous, a *field-specific vulnerability analysis* can be conducted (based on Farm Survey)

- Optional: If appropriate resources and skills are available, you can further expand the vulnerability analysis by:
  - Identification of (regionally specific) climate projections
  - Deriving potential impacts relevant for long-term farm development (>30 years)

Broadly speaking, a vulnerability and climate impact assessment aims at the identification of climate change induced threats for a specific system (UBA, 2017). This system could be a nation, a city, or a farm. The general goal of the process is to prioritise certain climate change threats and corresponding

adaptation measures. The common, science based procedure is to identify climate projections which cover the geographical location of the considered system, derive climate information, e.g. increase of hot days, and assess what climate impacts this change in hot days will have on the considered system. This process normally requires a lot of time, resources and expert knowledge. All three factors are scarce at the farm-level. Still, it is essential to identify core vulnerabilities and prioritize adaptation measures. Consequently, we need to adjust and facilitate the approach of vulnerability and climate impact assessment to be useful at the farm-level.

SWOT-Analysis

The farm vulnerability analysis consists of two steps. First, the current vulnerability of the farm is analysed. In the ClimateFarming Cycle, a simple SWOT-Analysis is used. The SWOT-Analysis serves to identify farm-specific *Strengths* and *Weaknesses* as well as possible *Opportunities* and *Threats*. *Strengths and Weaknesses* refer to internal factors, while *Opportunities and Threats* include external factors, which are normally collected in a SWOT-Matrix. Internal factors include physical, financial and human resources (e.g. soil quality and land area, equity for investments, available knowledge and skills, etc.). External factors include input prices, markets, consumer habits and trends, technology and policy frameworks. The Farm Survey (Step 1) can serve as a basis for the analysis.

The aspects collected in the SWOT-Analysis are not necessarily related to climate change - other factors can be relevant too, e.g. a well functioning direct-marketing channel (*Strength*) or high weed pressure (*Weakness*). However, if the farm members identify the increase of spring droughts at this point as a threat, this can and should be integrated in the SWOT-Matrix and will be discussed again later in the climate impact exploration. The goal of the SWOT-Analysis is to get a good insight of the present situation of the farm, as many of the current issues of the farm can be amplified by climate change. Consequently, the vulnerability of a farm can already be reduced by addressing its current issues without implementing actual adaptation measures.

Example: A dairy farm suffers from low clover-grass yields with low quality and consequently low milk yields. The investigation of the farm in the scope of the Farm Survey and the Soil- and Site-Analysis shows a nutrient imbalance which most probably causes the low yields and qualities. This imbalance can be addressed by specific inputs or adjustments in the crop rotation, which should stabilize yields and improve farm profitability.

This exemplary issue is not caused by climate change, but could be aggravated by extending drought periods or erosion events. As a consequence, addressing current farm issues (or taking advantage of chances) is not always directly connected to climate change, but can help to reduce a farm's vulnerability to future climate impacts. It can be stated: a well functioning and profitable farm with healthy soils and animals in the present is less likely to be negatively impacted by climate change in the future. However, in order to secure this success, climate impacts must be considered in the planning too, which leads to the second part of the farm vulnerability analysis

Additional Method 1: TOWS-Analysis

In the case of a complex farming system with different production branches and/or an excessive high number of identified SWOT aspects, the TOWS-Analysis could be a reasonable complementation of the vulnerability analysis. A TOWS matrix is comparable to a SWOT matrix, but contains four additional blocks which focus on the interactions of the individual SWOT elements and serves the preliminary formulation of strategies to address the different SWOT aspects. More information on the method can be found in the *ClimateFarming Trainer Handbook.*

Co-funded by
the European Union

Climate Impact Exploration

As mentioned in the beginning, an elaborated climate impact assessment based on regionally-specific climate projections is in most cases not possible to be conducted at the farm-level. Still, it is important to explore how certain changes in climate parameters and especially in extreme events can affect the specific farm system.

For this purpose, the ClimateFarming Cycle takes an explorative approach, mostly based on *"The Vulnerability Sourcebook"*, published by the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* (2017).

Based on the expert-knowledge of the farm members and the advisor, past weather phenomena and extreme events are collected and their impact analysed (compare Step 1: Farm Survey). Following, observed trends and possible future climate impacts are collected and clustered. Afterwards, these different impact clusters can be graded and prioritized.

Past Climate Impacts

The participatory process starts with the following discussion questions *(GIZ, 2017 - modified)*

1. What weather phenomena and extreme climate events have impacted your farm in the past? (e.g. drought periods, heavy precipitation, heat waves)
2. Have you observed any new trends or recent events (i.e. in the last decade)? (e.g. extending spring droughts, more sun hours)
3. What impacts have you observed in the past as a result of these climate events (e.g. loss in yields, increase in disease)?

First, the past weather phenomena and events are collected. Especially interesting are extreme events like floods, drought periods etc. Likewise, the farm members collect rather recent trends they experienced. Following, the farm members write down how these past phenomena and events impacted their farm and connect the impact with the corresponding event.

Future Climate Impacts

Following, the possible future climate impacts on the farm will be explored. For this purpose, the discussion questions below can support this process:

1. Temperature: How could it impact your farm when temperatures increase? Is it important whether spring and/or autumn get warmer (important link: late frost days)?
2. Hot Days: How could it impact your farm if the number of hot days (>25-30°) and heat waves increase?
3. Dry periods: How could it impact your farm if dry periods (consecutive days without rain) increase? When are dry periods especially problematic for your farm?

4. Precipitation: How could a change in precipitation impact your farm? How would a seasonal shift in precipitation affect your farm? Could heavy precipitation events be problematic? Could prolonged wet periods be problematic?
5. Frost: How could a decrease in frost days (< 0°C) impact your farm? How could a decrease in late frost days impact your farm?
6. Hail, Wind and Storm: How could a change in hail, wind or storm events impact your farm?
7. Sun hours: How could an increase in sun hours impact your farm?

These questions are just examples of how to structure a discussion in order to examine how different changes in climate parameters could impact a specific-farm. These questions do not cover all possible changes due to climate change and can and should be adapted to the individual farm, its structures and the specific region.

External and indirect Climate Impacts

Like the direct climate impacts above, indirect climate impacts and other external factors may influence your farm. The guiding questions below can be used to explore eventualities, so the farm can be as prepared as possible when unforeseen events happen.

1. **Energy/ external inputs:** How could your farm be impacted by high energy prices? Which external inputs are you dependent on and how would low availability/ high prices impact your farm?
2. **Workforce:** How could your farm be impacted if there is a lack of available workforce? Or if weather conditions are so poor that productivity is seriously impaired?
3. **Contractors**: How could your farm be impacted if external contractors would not be able to perform their services for you?
4. **Market**: How could your farm be impacted if the products you offer are not in demand? Or if your marketing strategy does not work anymore?
5. **Pests and diseases:** How could your crops or animals be impacted by upcoming or new pests and diseases?
6. **Other questions:** Feel free to develop your own, farm-specific questions to explore how the farm is probably affected by indirect climate impacts

Limitations

The exploration of climate impacts based on expert knowledge (farm members and ClimateFarming Consultant) is an approach of integrating potential climate impacts in the farm-specific vulnerability analysis without being dependent on the availability of adequate climate projections and the expert knowledge to understand and interpret these projections. This approach is optimized for the usage at the farm-level, but it is important to be aware of its limitations. The results are highly dependent on the persons assessing the climate impacts and also how they perceive related risks. Consequently, the climate impact exploration is a way to integrate climate impact considerations in farm-level decision-making, but it is not comparable to a sophisticated climate impact assessment, based on a scientific procedure with higher input of resources and specialized knowledge. When in doubt, it is always advisable to contact expert services to analyse how a certain climate impact can impact a specific farm. In the case of long lasting investment decisions, it might also be helpful to consult services which are capable of providing and analysing regionally specific climate projections, so that potential climate impacts can be derived with more certainty.

After collecting past and possible future climate impacts, the next stage is to prioritize the different potential impacts. For this purpose, the findings of the previous SWOT-Analysis are used.

Combining SWOT-Analysis and Climate Impacts

In order to prioritize climate impacts, the farm members take the SWOT-Analysis and assess which *Weaknesses* or *Threats* could be aggravated by the identified climate impacts. The *Weaknesses* and/or *Threats* which are getting worse when the climate impacts are considered can be marked as priorities for the following formulation of adaptation measures (Step 3).

Furthermore, it can be possible that the climate impact exploration revealed new and/or not discussed aspects for the SWOT analysis. If this is the case, also these additionally discovered *SWOT* aspects should be added.

Should the results of SWOT-Analysis not be further impacted by the potential climate impacts, a prioritization can also be achieved by discussion. A simple option is to grade the *Weaknesses* and *Threats* regarding their relative importance for the farm and its future development. Analogous, the grading procedure can be applied to the explored climate impacts.

Excursus 1: Climate Projections

Climate projections are always subject to uncertainty, as explained in section Climate Change Management in the Trainer Handbook. However, they can still provide valuable information about the future climate and support the planning of climate strategies. In the ClimateFarming Cycle, climate projections are not directly integrated, as the usefulness of climate projections for farm-specific vulnerability analysis is highly dependent on the resources available, as well as the expertise of the consultant. The knowledge and time needed to find, understand and interpret appropriate climate projections is generally outside the scope of an agricultural consultant. Furthermore, the importance of climate projections for farm-level adaptation planning should not be overrated, as an individual farm is not predominantly affected by the average changes in climatic parameters, but the inter- and intra-annual weather variability as well as extreme events.

Nevertheless, climate projections can provide guidance on the overarching trends and long-term developments. Consequently, the utilization of climate projections is especially useful for long-term planning (>30y), for example long-lasting investment decisions like a new dairy cattle house. Different sources for professionally prepared climate information exist. For instance, the Climate Service Center Germany (https://www.gerics.de/) offers fact sheets on individual districts in Germany. These are written in a generally understandable way and form a good basis for discussion.
If a consultant decides to work with climate projections, they should become familiar with the theoretical background of climate projections and how to interpret the available data. A good starting point is the publication *"Leitlinien zur Interpretation regionaler Klimamodelldaten"* (2023), available at https://lfu.brandenburg.de/sixcms/media.php/9/Leitlinien-Klimamodelldaten.pdf.

Sources for Climate Information (Climate Projections)

- https://www.climate-service-center.de/products_and_publications/fact_sheets/climate_fact_sheets/index.php.de
- http://climexp.knmi.nl/start.cgi
- https://www.nccs.admin.ch/nccs/de/home/klimawandel-und-auswirkungen/schweizer-klimaszenarien.html
- https://climate.copernicus.eu/
- https://climate-adapt.eea.europa.eu/en/knowledge/c-a-indicators/c-a-indicators

Sources for Agricultural Climate Information

- https://canari-europe.com/
- https://www.adapter-projekt.de/klima-produkte/klimakalender.html

Step 3: Collection of adaptation measures

IN A NUTSHELL

- Guiding question(s): Which adaptation measures potentially fit our farm, our farm objectives and correspond with our farm's vulnerabilities? Which adaptation measures address field-specific problems or opportunities?
- In step 3, various adaptation measures are collected and evaluated on a farm-specific basis. The overall goal of all adaptation measures should be to address the concerns and/or chances identified in Step 2. Adaptation measures can reduce risk, moderate negative effects and/or exploit opportunities arising from climate change. It is important to be aware that adaptation measures can also entail new risks and uncertainties. It's not always possible to name and deal with these before actual implementation, but discussing potential trade-offs is a first approach to reduce the risk.
- Step 3 entails following tasks:
    - Equipping the farm members with adequate resources to search for farm-specific adaptation measures
        - Links are provided in the ClimateFarming Cycle Handout
    - Collecting a wide variety of adaptation measures
        - If applicable: collect field-specific adaptation measures
    - Assessing adaptation measures:
        - Categories: Climate adaptation; profitability; ecological, social and other effects; maladaptation potential
    - Deciding which adaptation measures are further used for Step 4 and which are categorised as “reserve measures”

Selecting Adaptation Measures

The aim is to collect a wide variation of different adaptation measures in order to address uncertainty by increased redundancy and flexibility. If possible, different time scales should be covered. How to set these different time-scales should be adjusted to the individual farm. In the scope of the ClimateFarming Cycle, short-term refers to the upcoming 0-5 years, medium-term to 5-20 years and long-term to >20 years. As there is a high diversity of different adaptation measures in agriculture, it is important to use the findings from Step 1 and Step 2 as a basis for a pre-selection.

Example of farm-specific collection of adaptation measures: If the vulnerability analysis of a farm reveals mainly problems associated with prolonged dry periods in the specific region, the research should focus on measures that increase water storage capacity, infiltration rate and overall water use efficiency. If necessary, income diversification measures should even be considered in the long term in order to moderate farm losses during dry periods. However, the consultant should ensure that a wide variety of measures are included in the catalogue so that still various possible developments are covered. For example, the risk of heavy rainfall and corresponding precautionary measures should be discussed - even if drought is the acute problem. Above this, the consultant is obliged to motivate the farm members to think outside existing structures and habits, for example whether new production branches could be possible.

Assessing Adaptation Measures

As soon as an adequate number of adaptation measures has been collected, these go through an assessment based on discussion questions. This should be done in a systematic manner in order to reduce the influence of subjectivity. First, it is determined whether a measure is theoretically capable of addressing the farm's vulnerabilities, as assessed in Step 2. Due to limited resources at farm level, this evaluation will be based largely on the expert knowledge of the ClimateFarming Consultant and the farm members, including the results from the field-specific Soil- and Site-Analysis.
Although detailed analyses cannot be conducted for all measures, insights from scientific work or practical examples can provide orientation for the evaluation. It is important that not only the adaptation potential of a measure is analysed, but also aspects like economic viability, labour input, climate protection potential and other ecological or social effects. Important for consultants and farm members alike is not to get lost in the acquisition of knowledge due to the vast availability of resources, data and potentially contradicting information.

The following is the maladaptation check. The maladaptation check will be based on the *Precautionary Framework* and the *Pathway Framework* (Magnan et al., 2016; Hallegatte, 2009; Barnett and O'Neill, 2010). As there is no measurable parameter for the risk of maladaptation, the maladaptation check can only be conducted qualitatively. The individual categories and explanations are summarised below. It should be noted that the categories may partly influence each other and overlap.

- **No-regret measure**: A no-regret measure has a positive effect on the farm, regardless of the development of climate change. An example of this is humus build-up, which fulfils important functions in the context of climate change, but also delivers many benefits for the farm and the environment apart from climate adaptation.
- **No increase in GHG emissions**: If possible, a measure should not worsen the farm's CO2-footprint and thus not further intensify climate change in terms of intensity and speed.

- **Reversible and flexible**: Measures that can be easily modified (flexible) or reversed (reversible) are generally less likely to lead to maladaptation. Testing new crops (e.g. chickpeas) is a flexible measure and can be changed again in the following crop year (reversible), whereas the construction of a new air-conditioned cattle shed is only flexible to a limited extent and not reversible (in the short to medium term).
- **Shifting negative effects**: Adaptation measures can reduce one's own vulnerability, but at the same time have negative effects on other persons, actors or environmental systems. This should be prevented.
- **Testability**: If a measure can be tested without major (financial) risks and is reversible without major costs/circumstances, this reduces the risk of maladaptation.
- **(Income) diversification**: The diversification of the farm, particularly of production branches and farm income, enables the farm to deal with extreme events and shocks. For example could the income derived from animal husbandry moderate losses in arable crop production due to new pests or a severe hail event. In order to safeguard the success of diversification, it must be assessed whether the individual production branches depend on each other and/or are susceptible to the same (climatic) impacts.

- **Reduced dependency:** Dependencies on certain inputs (e.g. import of animal feed, fertilizers, fossil fuels etc.) increase the farms vulnerability concerning disturbances in the supply chains (e.g. due to extreme weather events) and price volatility. Reduced dependencies are consequently associated with reduced risks. However, dependencies in general do not necessarily entail higher risks and can actually support farm-level adaptation, e.g. via cooperation with other farmers. Still, it must be considered that dependencies increase the uncertainty how climatic and non-climatic impacts will affect the individual farm.

As soon as an adaptation measure passes through the individual assessment steps, it will be categorised as potential measure for the *Farm Climate Strategy* (Step 4) or set back as reserve measure until new developments probably change the utility of the measure.

Step 4: Farm Climate Strategy

IN A NUTSHELL

- Guiding question(s): Which adaptation measures fit together? Where do synergies or conflicts arise? What climate resilient development opportunities exist for our farm?

- Step 4 aims at organising the individual adaptation measures from Step 3 in a Farm Climate Strategy. The farm climate strategy should provide the farm members with a roadmap that specifies which adaptation measures can be tested or directly implemented , which measures should be planned and prepared for , and which perspectives exist for climate-adapted farm development. The overall goal is to maximise synergies between adaptation measures, reduce conflicts and link short-, medium- and long-term measures.

- Step 4 entails following tasks:
  - Arranging adaptation measures from Step 3 along a time axis to develop a farm climate strategy
  - Assessing the farm climate strategy with Multi-Criteria-Analysis to identify possible deficits of the farm climate strategy
    - Recommended categories are:
      1. Resilience proxies
      2. Climate protection
      3. Costs (investment)
      4. Side effects (e.g. biodiversity)
  - Modifying the farm climate strategy if necessary
  - Analogous, a field-specific adaptation strategy can be developed

- Optional: Evaluation of the farm climate strategy with a second SWOT-Analysis and formulation of Contingency Actions

Once a comprehensive collection of farm-specific adaptation measures has been compiled, this collection can be used for the development of the farm climate strategy, which should not only comprise the next five years, but also entail long-term goals (e.g. >20 years).

Example farm climate strategy: In order to react to recent drought periods, the farm members decide to implement the diversification of their crop rotation as a short-term measure. For the mid-term, the farm members plan to develop a first agroforestry system in order to reduce evapotranspiration on the field. For the long-term, they formulated different adaptation measures, depending on how climate change will develop. These long-term measures include the expansion of agroforestry, the usage of irrigation systems or income diversification.

After the farm members decide on a farm climate strategy, the developed farm climate strategy is going through an assessment. Basically, this can be done with many different methods, mainly depending on the available knowledge and resources of the consultant and the farmers. Due to the focus on the farm level, multi-criteria analysis is used in the ClimateFarming Cycle. The aim is to examine different aspects that are important for the success of the farm climate strategy. Which aspects these are generally depends on the individual farm and strategy, but the ClimateFarming Cycle recommends an investigation and evaluation in the areas of resilience, investment costs, climate protection and side effects. The decision trees from the ClimateFarming Cycle handout can provide guidance here. As mentioned in Step 3, the level of detail of the evaluation should be adapted to the specific farm. If the evaluation identifies strong deficits in one or more of the categories, the farm climate strategy should be modified.
In practice, it has been shown that the evaluation of the farm climate strategy is mainly based on the adaptation measure assessment from Step 3. However, it is important not only to look at the sum of the measures, but also at synergies and conflicting goals between the individual measures.

Multi-Criteria Analysis

Resilience proxies:

The resilience proxies of the ClimateFarming Cycle are based on Ben-Haim (2019), who defined five different proxies that can provide guidance in assessing an adaptation measure or a strategy. It is important to note that the different factors overlap and influence each other.

- Recovery: Rapid recovery from negative, surprising developments. Recovery is defined as reaching the farm objectives.
- Redundancy: Many different options (adaptation measures) exist to deal with new developments. Higher resilience is attained by a high variety of response options to surprises.
- Flexibility: The farm and its characteristics can be changed quickly as conditions change.
- Adaptivity: The flexibility of a farm to adapt itself in the medium to long term. This includes the modification of goals and methods according to changing conditions.
- Comprehensiveness: Resilient decision-making integrates multiple perspectives and seeks to consider all factors that make up a problem (e.g. technological and cultural aspects, socio-economic factors, etc.).

The consultant and company staff now examine the extent to which the farm climate strategy that has been developed fits with the demands of the five categories. Since there is no way to assign a measurable value to resilience, this is done qualitatively with the help of discussion questions.

Costs:

Future costs of an adaptation measure - and a farm climate strategy - can have different sources. On the one hand direct costs associated with investments, e.g. for new machinery. On the other hand, costs can occur from rising labour requirements, losses from experimentation and learning or time-investment in knowledge acquisition. Another important aspect are transfer costs, which arise when a farm must change from one adaptation measure to another. These costs are difficult to calculate beforehand, but should be considered in decision-making.

Due to this uncertainty about the actual future costs of adaptation, the ClimateFarming Cycle pursues the approach to evaluate investment cost based on the comparison with the average investments of

the specific farm in the considered time period. The process can be conducted analogous for the labour costs or other factors.

How the economic evaluation of the farm climate strategy is ultimately carried out depends on the available capacities of the farm and the ClimateFarming Consultant. The more detailed an economic assessment can be carried out, the better for decision-support. However, attention must be paid to not get lost in the preliminary evaluation.

Example of transfer costs: A farm with intensively irrigated vegetable production invests in a more efficient, but very expensive, new irrigation system. However, due to declining groundwater levels, the usable amount of fresh water for irrigation is constantly rationed and vegetable production is no longer possible in its original form. Should the farm now consider switching to water-extensive cropping or other income-generating activities, the investment in the new irrigation system has increased the transfer costs. This means that the costs of moving from one adaptation measure to the next adaptation measure have increased due to the investment.

Climate protection:

How the climate protection potential of a farm climate strategy is evaluated is again limited by the available resources. For example, a trend can be derived on the basis of the individual adaptation measures and their climate protection potential, based on literature research. This approach was used in the SOLMACC project, in which innovative management practices on 12 European farms were researched (https://solmacc.eu/). More sophisticated are calculation tools, such as the *Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V.* (KTBL) standard for individual farm climate accounting (*Berechnungsstandard für einzelbetriebliche Klimabilanzen* (BEK); KTBL, 2021). The BEK "[...] enables interested parties to carry out greenhouse gas calculations themselves, to develop their own calculation programmes according to the BEK or to compare existing calculation programmes with the BEK." (https://www.ktbl.de/themen/bek). It is important to acknowledge that the climate protection assessment in the ClimateFArming Cycle only serves the purpose of orientation and can not replace a sophisticated CO2-footprint.

Ecological, Social and other Effects:

Ecological and social side-effects, whether positive or negative, are usually difficult to measure (e.g. biodiversity). However, to ensure that these important factors are not forgotten when assessing a farm climate strategy, possible side-effects should be recorded at least qualitatively.

Additional Methods 2: SWOT-Analysis and contingency measures

Using SWOT-Analysis and contingency measures is not pivotal for the success of Step 4 and the ClimateFarming Cycle and can be skipped if necessary. However, it is a worthwhile method to evaluate the developed farm climate strategy, as it motivates the farm members and the ClimateFarming-Consultant to critically analyse the developed strategy and open up options on how to further improve the resilience of the farm climate strategy.

The SWOT-Analysis of the farm climate strategy serves to identify uncertainties, new vulnerabilities and opportunities arising from the farm climate strategy. The analysis is the basis for the formulation

of contingency actions. Contingency actions have the purpose to increase the resilience of the farm and its plans by hedging its success or exploiting arising opportunities. Three categories exist, namely *defensive*, *corrective* and *opportunity actions* (Walker et al., 2019). More information can be found in the ClimateFarming Trainer Handbook.

Additional Methods 3: Adaptation Tipping Points and Opportunity Tipping Points (ATP and OTP)

When implementing the farm climate strategy, the question arises when a new or a complementary adaptation measure should be introduced and implemented. In difficult cases, the concept of Adaptation Tipping Points (ATP) can help. If a farm climate strategy has a large number of adaptation measures, especially in the medium and long term, ATPs can help to guide the implementation or introduction of adaptation measures. In theory, an ATP is a defined threshold value of an indicator that indicates that a current adaptation measure is no longer effective and a new one should be implemented (Haasnoot et al., 2013).
In addition to ATPs, opportunity tipping points can be defined. In contrast to ATP, these indicate when it would be viable to implement an adaptation measure. Such a tipping point can be certain threshold values of an indicator, but also certain events or developments. More information can be found in the ClimateFarming Trainer Handbook.

Step 5: Monitoring and implementation

IN A NUTSHELL

- Guiding question(s): How can we monitor the effectiveness of our farm climate strategy? Which adaptation measures can we implement directly, which can be tested, which do we need to plan and prepare? Do the implemented adaptation measures work properly? What can we learn from this? What changes can we observe? How do we have to react to them?

- Step 5 is the transition from planning to practical implementation. It provides an orientation on how the success of the farm climate strategy should be monitored and how to start the practical implementation of the first adaptation measures.
  The monitoring has two parts: The first part is the subordinate monitoring, which controls whether the farm climate strategy as a whole is successful (=fulfillment of farm objectives). This should inform the farm members whether modification of the farm strategy is necessary.
  The second part of monitoring is connected with the individual adaptation measures. Planning and conducting the practical implementation of a measure is always accompanied by a measure specific monitoring plan.

- Step 5 entails the following steps:
  - Collecting indicators that specify which internal factors (e.g. yield, income, workload, etc.) and external developments (changes in climate parameters,

technology, market changes, etc.) are important for the achievement of farm objectives and should be monitored.
    - Clarifying responsibilities concerning monitoring
    - Designing a regular review event: check the farm climate strategy and the achievement of farm objectives in regular intervals (e.g. once a year).
    - Scheduling the implementation of short-term measures; clarifying responsibilities for implementation
    - For measures which should be implemented right away: develop an implementation and monitoring plan
    - Optional: Checking whether certain contingency actions can be implemented
- Tip: The Cheat-Sheet Indicators for Monitoring supports farm members and consultants in monitoring the individual adaptation measures and selecting meaningful indicators.

Monitoring and learning are fundamental aspects of adaptation planning and strategic farm management. The first action is to collect relevant indicators which should be monitored in order to control the success of the farm climate strategy and to track the achievement of farm objectives. The aim of these indicators is to inform the farm members concerning the development of internal and external changes. Based on the monitoring of these indicators, the farm members (and the ClimateFarming-Consultant) can decide whether new or complementary adaptation measures are needed or if the farm climate strategy needs to be fundamentally revised or replanned.
The indicators should entail external factors such as climate and environmental changes, technological development, economic, political and cultural changes, but also internal aspects such as working hours, yield, income or job satisfaction. The continuous monitoring of these indicators is supposed to enable the farm members to recognise relevant changes at an early stage and to act proactively. Together with the collection of indicators, the question of who, when and how certain indicators are checked should also be clarified.
The indicators and related monitoring should be developed as farm-specific as possible, so that they fit the farm's climate strategy, can be monitored by the farmers and provide important information for the farm. The same applies to the field-level, as described in the Soil- and Site Analysis.

Regular review events are another approach to effective monitoring. These are regularly scheduled events at which the farm climate strategy and the underlying assumptions[2] are checked, for example once per year after harvest. Here, the farm members can discuss whether farm objectives are fulfilled, which adaptation measures are working fine, which must be modified, complemented or exchanged by other measures. Likewise, the status of mid- and long-term measures can be reported. If necessary, the modification or the re-planning of the farm climate strategy can be discussed at the regular review event. In essence, basically the same questions and aspects as during regular monitoring are discussed, but in a systematic manner. Consequently, the guiding questions of monitoring can also provide guidance for the regular review event.

[2] Underlying assumptions in this context means the cornerstones of the farm climate strategy. Examples could be the availability of land (lease agreements), the sufficient availability of irrigation water, a secure sales market for direct marketing or the expertise of certain farm members.

- Guiding question(s): Do the implemented climate measures meet our farm objectives? What works, what does not work? What can we learn from this? What changes can we observe? How do we have to react to them?
- Based on the monitoring, the farm members decide on:
    - Modification of implemented adaptation measures
    - Introduction of new or complementary adaptation measures
    - Modification of the farm climate strategy
    - Necessity to re-plan the farm climate strategy or re-run the ClimateFarming Cycle.
    - Integration of new knowledge and lessons learned into the farm climate strategy and adaptation measure implementation
    - Optional: Implementing contingency measures

Start Implementation and Monitoring

In Step 5, the adaptation measures that were categorised as short-term measures in Step 4 are planned and prepared for implementation or testing. If applicable, contingency measures that directly address these measures or current deficits of the farm climate strategy can also be prepared for implementation. Short-term measures that are not supposed to start in the near-future (e.g. the next year) are planned. In addition, responsibilities for the various adaptation measures and their implementation and monitoring are discussed and determined.
At the same time as the first measures are implemented, monitoring begins. This applies to the farm climate strategy as a whole, but also to the individual, implemented measures. Depending on the measure, it should be a minimum requirement to develop and adhere to a measure-specific monitoring plan at the latest with the implementation. Here, too, external consultants can be involved.

For the farm climate strategy, the specified indicators as well as the defined farm objectives should be monitored. Here, the regular review event in particular should be mentioned as a central tool.
If monitoring indicates the implementation of a new measure, it will be prepared and implemented. Same applies to contingency measures if applicable. If the monitoring identifies fundamental deficits in the farm climate strategy or detects profound internal or external changes, a new planning of the farm climate strategy and, if necessary, a new run of the ClimateFarming Cycle must be initiated.
In addition to monitoring the farm climate strategy, the selected indicators should be regularly reviewed (e.g. during the regular review event) for their information content and practicability.

Example variability: The distinction between interannual variability and actual climatic changes is problematic and must be kept in mind when making decisions. The drought-period in Germany between 2018 and 2022 is a good example. Although dry conditions were the prevalent issue for farmers in Germany (and many parts of Europe) at this time, a farmer should not be tempted to think that these years are evidence for how the next five years (or the future in general) will look like. There will be drought periods again, but likewise, wet years and heavy precipitation events can occur. At this point, climate projections can help to distinguish outliers and actual trend changes.
However, this does not only apply to climate change, but also to fluctuations in market prices or consumer preferences, for example. How certain signals are interpreted is usually very subjective and depends on the experiences and assessment of the individual person.

Co-funded by
the European Union

Excursus 2: Indicators for Monitoring

In order to ensure the measures that are implemented on a farm are working, a monitoring and evaluation plan needs to be made. Find a list of indicators in this external Excel File: Indicators for Monitoring: Success of Measures and Climate Change Impacts.

This list should help you to find indicators that are suitable for an evaluation of the impacts of the implemented measures. However, this list is not exhaustive by far, it should rather give you some ideas on what to look for. A monitoring plan, just like a new measure, needs to be tailored to the needs and context of the farm and the people implementing it. The consultant needs to thoroughly understand, or possibly exchange with a specialist consultant, what impacts the measures could possibly have. However, some impacts might be unexpected, so it is also good to not only look for the obvious.

You can also find other indicators and methods for monitoring from an agroforestry monitoring project (that can also be used in different contexts) here: https://agroforst-monitoring.de/Methodenkatalog/. You could also check out certification schemes like https://regenorganic.org/ or https://savory.global/eov/ or this offer that calculates the value of socio-ecological services on farms https://www.regionalwert-leistungen.de/about-us/ to see what indicators they use. Feel free to do your own research and find the indicators and methods that fit your context and ressources the best.

This list is divided into indicators that evaluate the success of your measures directly and indicators that help you understand the impact climate change has around your farm over the years. On top of this, you could also monitor other external factors like market prices, new technologies, changes in consumer patterns, etc. to further monitor the food and farming system and thus the conditions you are working with. These factors may lead to different preconditions in some years and thus may necessitate filling out the Farm Survey anew and running the ClimateFarming Cycle again.

Which indicators are relevant and how you measure them is dependent on your context. Some indicators could be measured by yourself with simple methods, or be measured by an expert. E.g. analyse your soil with an extended spade analysis regularly with minimal cost, or you could send soil samples to a laboratory every few years. The frequency of measurements in the list should rather be seen as an approximate suggestion, in some contexts it might make sense to measure indicators more or less often than indicated. The degree of accuracy and frequency depends highly on the goals you set. Sometimes it may be enough to see a tendency whether a measure leads in the right direction of success or the opposite, sometimes you may want or need to prove the impact on paper. It could also be an option to get involved with universities, research institutes or citizen science initiatives for monitoring your progress.

Further on, one tends to be biased when investing time and resources into developing new ways of managing our fields, or building new infrastructure, marketing channels etc.. So of course one wants the measures to succeed and may unconsciously rate the baseline worse than it actually is, and the progress better than it is. This is called confirmation bias. The other way around might be true too if the potential of a measure is doubted from the beginning, which is called status quo bias. The best is to be aware of these biases and try to be as objective as possible. Further on, it is important for the same person to evaluate an indicator over the years, in the same place and take many notes and photos on the specifics of the measurements. It may seem obvious how and where you took soil

samples today, but it may not be as obvious in 3 years from now and you will be thankful for any kind of information about the last sampling.

This documentation of a farm's adaptation process is supposed to serve as a foundation for the continuous process of farm adaptation.

References

Arbeitsgruppe BEK (2021): Berechnungsstandard für einzelbetriebliche Klimabilanzen (BEK) in der Landwirtschaft. Handbuch, Darmstadt, Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V., 2. Auflage. In: www.ktbl.de.

Barnett, J. and O'Neill, S. (2010) Maladaptation. Global Environmental Change, 20, 211-213. https://doi.org/10.1016/j.gloenvcha.2009.11.004

Gesellschaft für internationale Zusammenarbeit (GIZ) (2017). The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. Bonn and Eschborn, Germany

Haasnoot, M., Kwakkel, J. H.,Walker, W. E., and ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global environmental change, 23(2):485–498

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. Global environmental change, 19(2):240–247.

Magnan, A., Schipper, E., Burkett, M., Bharwani, S., Burton, I., Eriksen, S., Gemenne, F., Schaar, J., and Ziervogel, G. (2016). Addressing the risk of maladaptation to climate change. Wiley Interdisciplinary Reviews: Climate Change, 7(5):646–665.

Umweltbundesamt (UBA) (2017). Guidelines for Climate Impact and Vulnerability Assessments. Dessau-Roßlau, Germany

Walker, W. E., Marchau, V. A. W. J., and Kwakkel, J. H. (2019). Dynamic Adaptive Planning (DAP). In Decision making under deep uncertainty: from theory to practice, pages 53–69. Springer Nature.