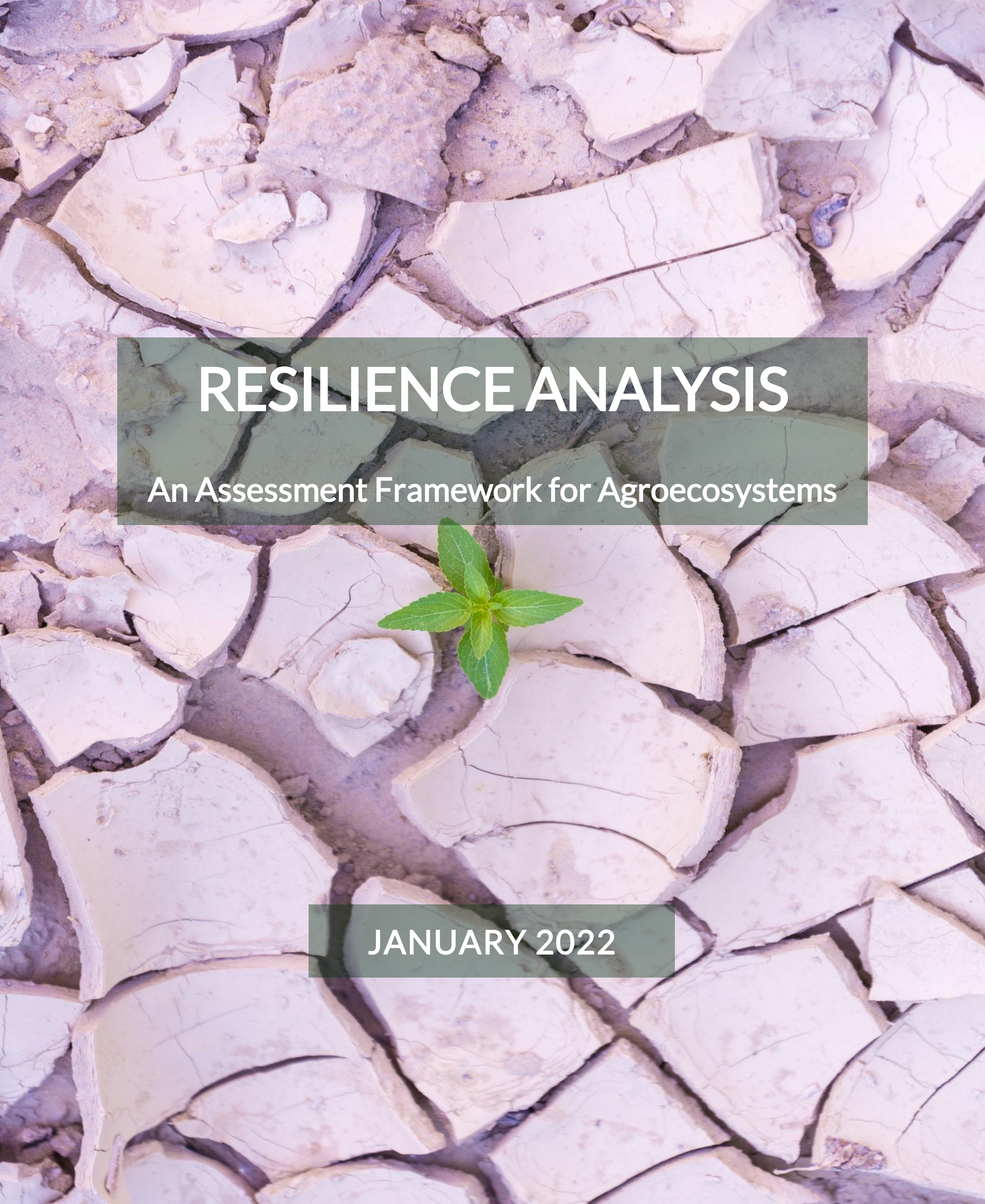

RESILIENCE ANALYSIS

An Assessment Framework for Agroecosystems

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CEEweb for Biodiversity

Resilience Analysis

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ACKNOWLEDGEMENTS

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INTRODUCTION

Agriculture is perhaps the most consequential form of cooperation between humans and nature. A total of 12.6 % of all land on our planet is cropland (USGS 2017) and more than 7 billion people are depending on this vast area every day since most of our food is produced by agriculture. At the same time, food production causes significant strain on the ecosystems being one of the main drivers of climate change, biodiversity loss and chemical pollution (Rockström *et al.* 2009; Gerten *et al.* 2020). These ecological effects have an increasingly damaging effect on agriculture itself — in the form of droughts, heavy rainfall, invasive species, disappearing pollinators, etc. Often, the response to these threats is even more intensified; however, sustainable and resilient responses to the new reality of the ecological crisis are also taking a foothold.

This methodology is based on the Resilience Assessment Framework (Resilience Alliance 2010), but it is constructed to be used more specifically for agroecosystems and targeted toward people who are less familiar with the concepts of resilience thinking.

Resilience thinking is different from traditional natural resource management. To assess and build resilience, agroecosystems need to be treated as *social-ecological systems* (SES) where people and nature are closely connected. In such systems, there is no chance to *govern* or *manage* the system from the outside. All humans involved are parts of the whole; no one understands all processes, no one can follow and analyse all changes that occur, but all stakeholders have experiences that are relevant to the understanding of the whole. Humans are part of the system and have an effect on it but have neither the power nor the knowledge to control it completely. Social-ecological systems have self-organizing capabilities. Self-organization means that the system gives responses to external effects in collaboration among its parts; the response depends on the state of the system. For the same external interference, the response can be entirely different depending on how this collaborative action is. It happens often that one effect that leads to a response will multiple times lead to a fundamentally different — and catastrophic — consequence next time. Self-organization also means that these systems have memory: past events change how the next response will unfold. A change in the system structure might happen very slowly and invisibly, but slow change can lead to drastic consequences when a threshold is crossed (B. H. Walker *et al.* 2012).

> "Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure." (Walker and Salt 2006)

Resilience thinking is focusing on the understanding of the self-organizing capability of SES. While drastic change is often catastrophic, self-organization also leads to resilience: the power of a system to bounce back, adapt and rearrange in front of a threat or pressure to save its integrity. Resilience is sometimes a purely ecological feature (e.g. when a forest regrows after windthrow) but, especially in agroecological systems, it often has a human component. Humans can build on resilience features; they can maintain them and help them to be strong when needed.

Resilience in agroecological systems is the capacity to adapt to pressures like droughts, floods, pest outbreaks, economic shocks, etc. Primarily as a consequence of climate change, these shocks will occur more often while industrial agricultural practices have changed landscapes across Europe to be less resilient. In every corner of the continent, it is just a matter of time when the impacts of the ecological crisis will surprise local farmers. While curbing climate change by reducing greenhouse gas emissions is a task on a continental (and global) scale, adaptation is local, it needs to be specific to every landscape and every society. This workbook helps stakeholders in agrarian landscapes to increase resilience and maintain mutually beneficial cooperation between humans and nature.

KEY CONCEPTS

Before starting to work, let us clarify three concepts that play a vital role in a Resilience Assessment process. We will approach agroecosystems as social-ecological systems and, within them, a few essential elements that are present in all of them. We will look for tipping points or thresholds that are limits — where the behaviour of the system changes dramatically. Finally, our approach to management will be adaptive management: an approach that explicitly builds on self-organization instead of trying to force solutions.

Social-Ecological Systems

SES can be seen as two densely connected subsystems: social and ecological. Both these subsystems contain slow and fast-changing components. Often, we are more interested in fast-changing components. As they change often (e.g. prices, game population, production of crops), we tend to pay more attention to them. Also often, these fast-changing components represent the elements we are more interested in since these form the basis for business income. Slow changing components might appear to be constant (e.g. soil quality, water table) but, in fact, these are slowly changing elements that define the stable structure of the system. Harvesting crops in one year does not change soil quality very significantly, just as digging another well does not change the water table visibly. Slow components are stabilized by various processes and play a particularly significant role in regulating the fast-changing components. Their stability, however, does not mean that they are unchangeable. A key question in a resilience assessment is to take slow components into account, assess their stability and monitor the forces that influence them. If slow components do change, the entire system might be altered with them, and it is much harder to control them directly. Slow components stabilize the system; thus, a resilience analysis must pay special attention to them.

Finally, an important class of elements are external factors. These cannot be changed from within the SES, but they affect the processes that take place inside. External factors can be shocks or just processes in larger systems that affect the agroecosystem with which we are working.

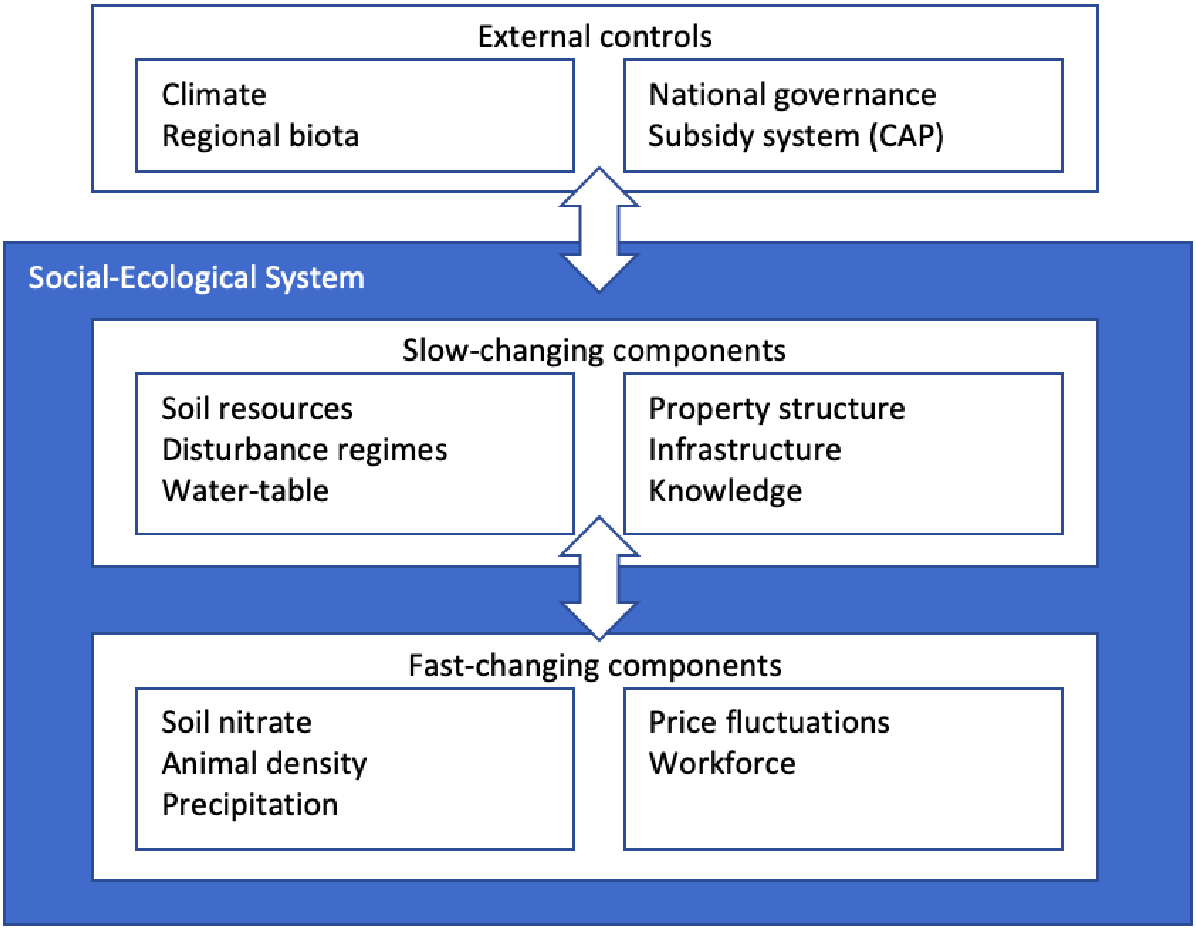


Figure 1. Basic structure of a Social-Ecological System (modified after Resilience Alliance 2010).

Tipping Points

When an SES changes, this can be gradual or sometimes sudden and unexpected. Sudden and unexpected changes happen after crossing thresholds. These are critical points, tipping points where the slow components have suffered enough damage not to be able to support the stability of the system in face of some new challenge. This new challenge is not necessarily unexpected in its magnitude — if a system erodes under pressure significantly, at some point usual and well-known shocks can also overwhelm its capacity to cope. When a system is resilient, its slow components stabilize it in a so-called stable state, where self-organization means resilience and the system endures all kinds of pressures. When the slow components are eroded, or the shock is too large, the system is not able to maintain its stable state anymore and flips to another state. This new state is also stable, but usually much less desired. The system has its self-organizing power after crossing the threshold, but in this new situation, the resilience of the new state will prevent humans from pushing the system back to its original state. Sometimes, it is possible to push the system back, but it requires a much larger effort than the prevention of crossing the threshold would have required. This phenomenon is typical in many complex systems.

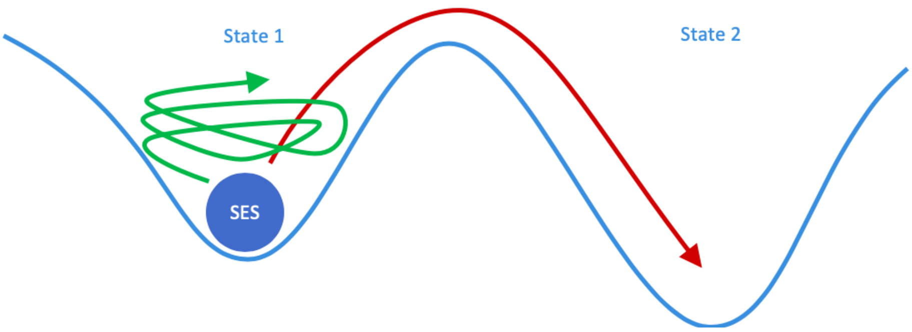


Figure 2. A ball and cup diagram. The two cups or valleys on this figure represent the possible stable states of the SES. The ball can wobble in the first valley if the forces shaking it are not too strong. A strong force can push it to the other valley, where it will find stability again, but in quite different conditions. The green arrow shows that a resilient system can maintain its stability if slow components are in good condition and the shocks are not overwhelming. The red arrow shows how a system crosses a tipping point if a shock is too large to withstand. This change is called a critical transition or regime shift (Scheffer 2009).

Adaptive Management

Adaptive management is based on the understanding that we have no fixed knowledge of an SES, just a limited understanding. In adaptive management, instead of policies, managers form hypotheses and, instead of management actions, they do experiments (Holling 1978).

Of course, existing knowledge is useful and necessary for successful management, but the knowledge might not be perfect, or the context might change; thus, constant monitoring and hypothesis-testing are necessary to re-validate our understanding of the system. Based on the current understanding, management actions are necessary, but their evaluation must explicitly account for the rationale behind them. It is also possible to pursue multiple different solutions for a single problem. Traditional knowledge and practitioners' experience are valuable sources of information.

Finally, adaptive management should not only build on the understanding of the biological system but the broader picture of social, economic and ecological processes. If a participatory approach is efficiently institutionalized, this method is called adaptive co-management. This approach is necessary not just because of the limits of human understanding, but because of the changing, self-organizing nature of SES. A practice that was well chosen and fruitful one year might not work well a few years later as external conditions (i.e. social, ecological) could change or the system itself evolves to a somewhat different shape. This means that even if — in theory — we had the perfect management decisions today, it might not work well next year; our understanding has to be refreshed constantly.

ABOUT THE RESILIENCE ANALYSIS PROCESS

On the following pages, a process is described in a workbook format. Similarly to the ideas in adaptive management, a Resilience Analysis (RA) is never complete. It is a circular process of understanding, planning, coordinated action and re-evaluation. Elements of the system change, and so do external factors. The starting point of an RA is the past, but novel challenges should be expected, monitored and integrated into the next round of resilience planning.

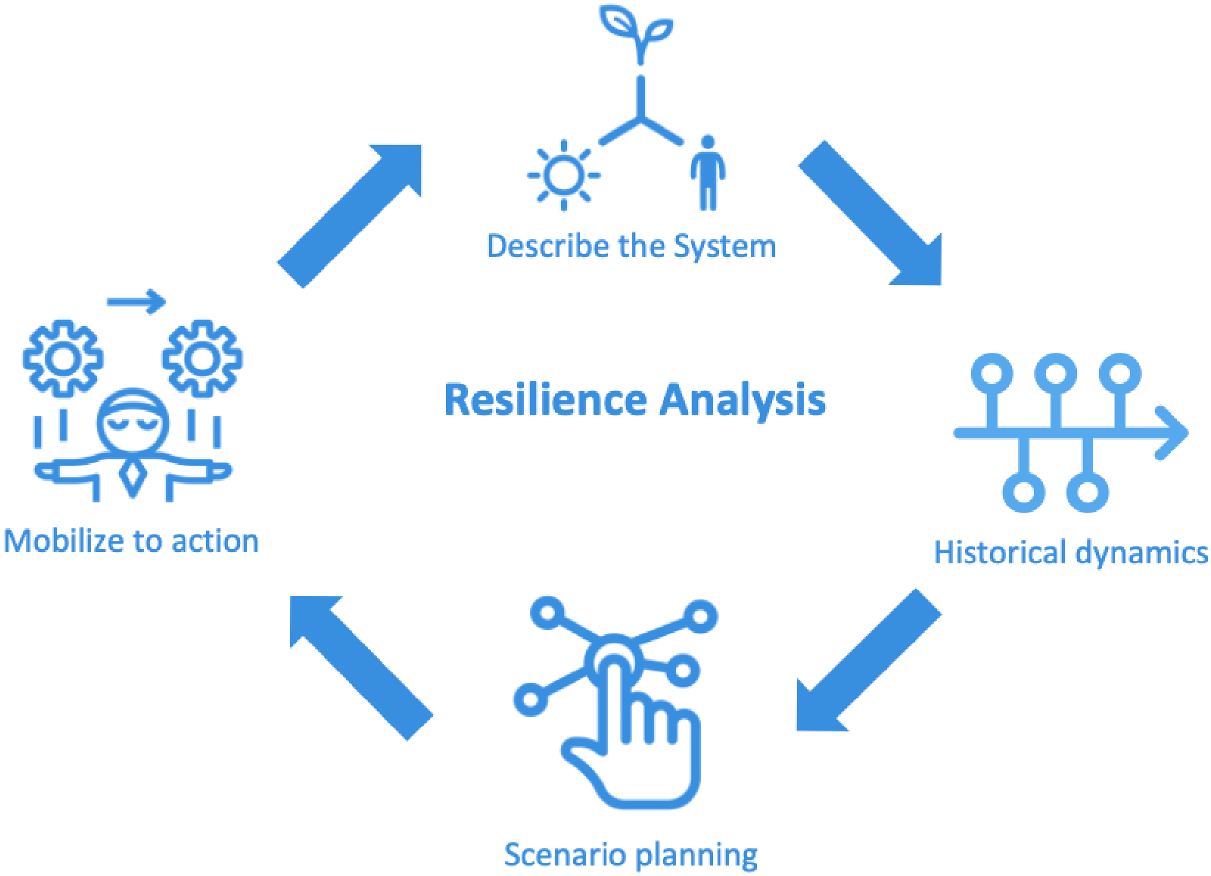


Figure 3. Overview of the Resilience Analysis process.

DEFINING THE SYSTEM

When a resilience analysis is done, usually there is already an issue of concern within the SES. It can be drought, declining income for farmers due to market changes, depopulation, etc. Different stakeholders might see this problem differently, but however it unfolds, it will affect all of them.

It is also possible that the resilience analysis is motivated by some problem that is foreseen but did not happen yet, such as some local effects of climate change or an anticipated collapse of the local population. In these cases, the use of available resources to transform into a more resilient system might be the main goal of this process. Needless to say, it is useful to define the main motivation that is shared by all participants. It is not possible to be resilient against everything: a defined common goal can help focus the process.

BOUNDARIES

First, system boundaries have to be defined. There is no perfect way to do this, but a few rules of thumb are good to be followed.

- **What are the biogeographical boundaries of the system?** Is there a well-defined landscape that forms a "whole" subsystem within its larger environment?
- **What is the spatial scale where the key issues unfold?** Think about the most important ecological and social processes that happen within the system. On what spatial scale can they be understood with a systemic approach (e.g. if our main concern is drought, a single farm is probably too small as a unit of action)?
- **Are there administrative boundaries that define who can act and where?** Often administrative boundaries set clear limits to management and, thus, define possible actions that can be taken after the resilience analysis.

These boundaries (e.g. boundaries of a national park) have to be taken into account.

- **Who are members of the local economic network?** Is there a nearby town or city that acts as a local market for farm products? Are there companies that act in the area? Even if they are not working in agriculture, they might have an impact on the purchasing power of the residents, on the accessible workforce, on the infrastructure development or on any other local development issue. The system boundaries are not just territorial limits, but also describe stakeholders who might influence the question of the analysis.
- **Who are the people who are affected or concerned by the challenges ahead?** Farmers, traders, local community, NGO-s, government officials, the tourism sector, etc.
- **What are the main factors that influence the agroecosystem but cannot be manipulated from within the system?** These can be, among others, various legal, economic, ecological, political and social factors.
- **What is the time horizon of our analysis?** What is the timescale of changes in the slow components of the system? How long do local stakeholders are willing to plan?

Figure 4. Defining boundaries. Within this example agroecosystem, there are croplands, wetlands, a settlement, a forest patch, grazing meadows, orchards, and infrastructure elements. From the outside, various factors influence the system but cannot be controlled: weather, market trends, legal environment, climate change, macroeconomic changes, politics and an emergent contagious disease. Some of these effects can be anticipated, some are surprises. Elements within the system are those that can be influenced by the decisions of stakeholders. The green line represents the chosen spatial boundary of the system. Its definition is, moreover, influenced by administrative, geographical and ecological factors.

Step 1

Specify the main issue that motivates the Resilience Analysis. It might affect different stakeholders differently. Collect various perspectives and describe what is the main value for each of the viewpoints. Consider economic, recreational, touristic, cultural, and conservation questions.

Table 1. Motivating issues. In this example, two key issues and four stakeholder groups were identified. Connected to the issues, they have described five different value aspects that are considered in the process.

ISSUE	STAKEHOLDER	VALUED ASPECT
Issue 1	Group 1	Value 1
	Group 2	Value 2
	Group 3	Value 3
Issue 2	Group 2	Value 4
	Group 4	Value 5

Step 2

Define the system boundaries:

1. Mark the spatial boundaries on a map — consider natural and administrative boundaries.
2. List all stakeholders considered — land users and concerned parties, as well as indirect users.
3. Define the time-horizon of the RA — consider slowly changing components.

SYSTEM HISTORY

Since workshop participants can usually relate to the system through personal experiences and domain-specific knowledge, an abstract and analytical method to model the whole social-ecological system may not work. On the other hand, reconstructing the history of the SES offers an overview of the evolution of the system, which is usually rich in detail and helps identify key system components. Reconstruction of history may also deliver consensus about the state and structure of the system that is necessary for scenario planning.

The end of the historical timeline is in the present; the beginning is to be decided by the participants. It begins in an age where the first events that happened are still influencing the present. It can be a historical event, a transformation of the landscape, immigration of current inhabitants, etc. In agroecosystems, it is useful to think about when this land became dominantly agricultural land.

On the historical timeline, (1) political, (2) social, (3) economic, (4) ecological, and (5) technological tracks are distinguished, and it is best to explore all these domains for all historical ages. Often, the interactions between them cause significant changes — such as technological inventions during the industrial revolution (which caused social and economic changes and is still having a significant ecological impact).

Step 3

Create a historical timeline with the workshop participants.

- Explore (1) political, (2) social, (3) economic, (4) ecological, and (5) technological aspects of historical development.
- Identify key events that changed the behaviour of the SES.

- Identify shocks that occurred once and recurring disturbances that belong to the system.
- Discuss changes in disturbance patterns.
- Identify periods when the system behaved consistently between two changes.
- Discuss what ecosystem services were exploited in these periods, what was their economic significance, and what changed their role (if any).
- Mark the most important causal relationships between the individual elements on the timeline.

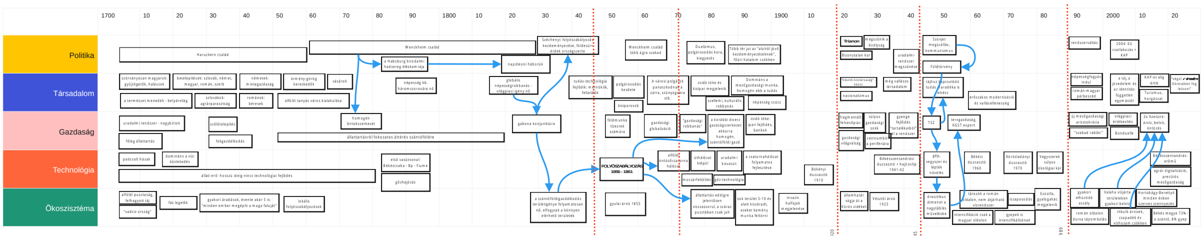


Figure 5. Example of a 300 year-long historical timeline to illustrate the structure.

Step 4

Identify slow variables. Slow components normally do not change much over time compared to the normal fluctuations in the system. For instance, pest populations, crop yield, honey production, grass biomass or bird populations might fluctuate rather fast, while soil conditions and the height of the water table tend to be much more stable. Humans are usually more interested in fast components as they are connected directly to the economic output of the system. Slow components are sometimes considered “constants” — even though they can change (unlike true constants) — this is a possible misunderstanding that could lead to serious problems. The stability of the slow components also limits the magnitude of fluctuations of the fast components. There is no specific method to identify slow components but there are some attributes that help to find them (Walker et al. 2012):

- Without external intervention, their change happens slowly compared to other system components. In an agroecosystem where crops are harvested a few times a year, change over 5-10 years is considered slow.
- They are connected to multiple ecosystem services — taking into account indirect connections, they might be connected to all.
- Their function is usually regulating and stabilizing the production of an ecosystem service.
- A sudden change in their state would radically transform the entire system (often in an undesirable way).
- They can be both social and ecological features in the system (an example of a social slow variable would be shared knowledge of high-quality wine production in a specific terroir).
- Usually, there are about 3 – 5 slow variables in an SES.

Slow variables help explain past changes and help build future scenarios in later stages. Their change or stability, depending on governance and external drivers, will most likely determine the future state(s) of the system.

SHOCKS AND PRESSURES

Disturbances are normal in all SES. Floods, droughts, forest fires, and pest outbreaks are part of the ecological processes. Ecological systems have co-evolved with their disturbances to the extent that they need them to survive in the long run. If no disturbances would happen, biodiversity would decline, the structure of the habitat would be less complex, and, eventually, the system might collapse entirely. In agroecosystems, maybe the most fundamental intervention of humans is to avoid disturbances to an extreme extent: suppress fires, avoid floods, stop insect outbreaks with chemicals, regulate inland water, irrigate when drought occurs, etc. Most certainly, these interventions lead to homogenization of the landscape; biodiversity declines and the whole system becomes fragile — more and more effort is needed to maintain the productivity in these kinds of agrarian landscapes (Uden et al. 2018).

While shocks are normal events in healthy ecosystems, agrarian landscapes do need to be prepared for two main reasons: (1) the vast majority of agroecosystems have low resilience due to the high level of human control and strategies to avoid all variability or shocks — so the memory of the SES "forgets" its preparedness for normal disturbances, and (2) due to climate change and other large scale changes new shocks are expected everywhere around the world. Building resilience, therefore, focuses on preparing for these surprises.

Three types of surprises

Generally speaking, SES can face three kinds of surprises. Adaptation to them is somewhat different, but there are similarities in the features that make a system resilient in all cases (Berkes, Colding and Folke 2003).

1. Shocks that are normal in the lifecycle of the SES but cannot be predicted precisely: these are events that have already occurred many times and that will occur in the future, but it is impossible to forecast *when* they will happen.
2. Surprise response for a known shock: when a system that has already encountered some shock or pressure and managed to adapt to it, sometimes, it suddenly gives a radically different response. These events are called *critical transitions or regime shifts* and usually can be explained by the erosion of the slowly changing components of the system.

3. New events: shocks that are *unprecedented, unexpected*, like industrial disasters, the emergence of new diseases, large economic shocks, etc. No system has a specific response for such events, but some are more capable of fast innovation and adaptation due to various factors. This ability of spontaneous innovative adaptation is called *general resilience*.

Three types of shocks

This typology is an alternative to the previous point from a more managerial point of view, focused on system connections and resource distribution in the present.

1. **Pulse**: is an event that happens suddenly, at a speed that is impossible to follow by the system's self-organization at first encounter (although the system may have specific capacities to regenerate after such an event). Forest fires and oil spills are examples of pulse shocks.
2. **Press**: is a process that is happening gradually over a longer period — yet, with a speed that evolution cannot follow — and the pressure slowly changes slow variables in the system. Depending on the system structure, resilience can be maintained for a while, while at some point the flexibility of the system might be overwhelmed. This is usually an event of a critical transition.
3. **Break:** is an event when a critical supply or sink suddenly stops working. This can be an economic supply chain, the disruption of an ecological corridor or a disturbance in some larger-scale infrastructure, such as an irrigation system. In a way, this is similar to a 'pulse' shock: it happens suddenly. As breaks are often non-ecological events, the supply of this function can often be restored after some time.

These typologies are useful when we try to identify what kinds of shocks are to be expected in a specific case. When we do a resilience assessment, one of the fundamental questions is *"Resilience of what to what?"* (Carpenter et al. 2001) In other words: how do we describe the system and what challenges do we expect? It is not possible to prepare for all kinds of surprises, but in a well-understood system, a wisely chosen list of expected shocks can be very helpful in the majority of practical cases. As there is no single best method for system modelling and there is no failsafe method for identifying slow variables, there is also no perfect way to prepare a list of all expected shocks. But a careful process built on science and practical knowledge of local experts can shape a well-grounded hypothesis about all of these — a hypothesis that can be tested and updated over time and that will help stakeholders to be prepared for the most likely threats they face.

Step 5

Identify expected shocks. The typologies described above, and the historical timeline compiled before help identify them. In this process, the first step is to list all shocks and disturbances that occurred in the past. The second step is to think about how known shocks have changed over the years (e.g. increased frequency). Finally, new challenges — that can be anticipated for any reason (e.g. climate change) — should be listed.

Fill in Table 2:

1. Did you identify press shocks in your system? These are often overlooked as they require a longer time to unfold.
2. Did any of the identified shocks have caused a major change in the way your system works? Often, these changes occur in values or other social aspects that drive the system.

Table 2. List shocks. The first column represents the name of the shock. 'Type' can be pulse/pressure/break. 'Recovery' is the recovery time after the shock (if already happened). 'Effects' show which system components were mainly impacted. 'Impact' shows the severity of the impact. 'Changes' describe changes in frequency, intensity, etc.

DISTURBANCE	TYPE	FREQUENCY	RECOVERY	EFFECTS	IMPACT	CHANGES
Past 1	Pulse	30 years	2 years	soil	severe	More frequent
Past 2	Press	20 years	10 years	economy	medium	NA
Present 1	Break	NA	NA	supply chain	severe	More expected
Future	Press	continuous	??	water table	severe	Increasing

Your results can be added to the historical timeline created in Step 3. Most probably, there were different periods, when the system was working — or managed — differently, and most likely not the same shocks and pressures were present during these times. Such an overview helps to think about possible futures. Not always, but it often happens that a major change in management happens as a response to a shock.

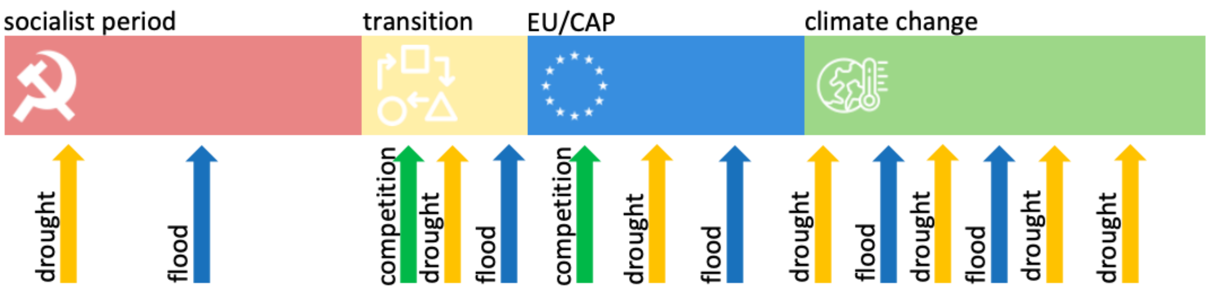


Figure 6. Timeline of stable states and shocks in an SES. This is a schematic example of an Eastern European country, where the end of the socialist dictatorship and the EU accession were major turning points. In the future, climate change might change agroecosystems fundamentally.

DYNAMICS OF CHANGE

Systems always change. Some of the changes are intended, some are coming from the outside but are welcome, and some other changes are to be avoided if possible. Sometimes, change is reversible; in other cases, not; and sometimes one change ignites a series of consequences that lead to a radically different future. There are cases when change is necessary to ensure the long-time survival of the system. Ecological, economic, political and social changes are often entangled.

STATE OF SLOW VARIABLES

Slow variables are defining the stability and resilience of the agroecosystem. If they have an optimal value, biodiversity, agricultural production and the local society thrive. As their value changes, the probability of a fundamental change (i.e. critical transition) increases. Unfortunately, it is impossible to know exactly where the threshold of change is. While slow variables have an eminent role in determining the system state, many other factors influence it, too. These other factors have a limited role but, closer to the tipping point, they might have decisive power due to the imbalance of the entire system.

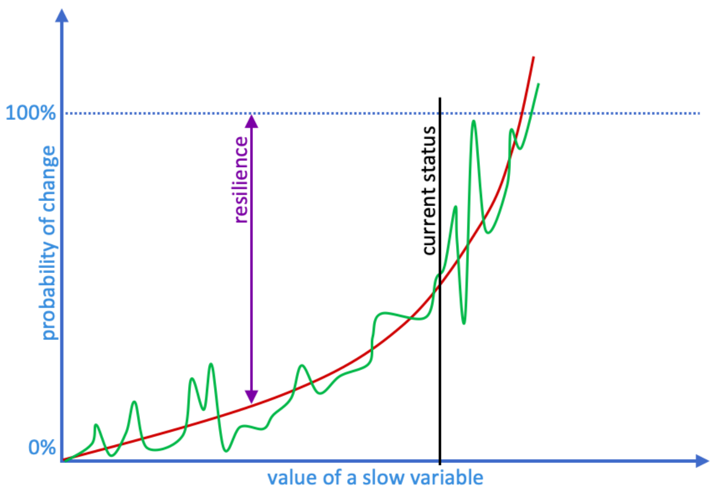


Figure 7. State of the slow variable and resilience. The red curve shows how the change of the slow variable increases the chance of a critical transition — in theory. The green curve shows what this might look like in real life due to fluctuations in other factors. The distance between the curve and the 100 % threshold is the resilience of the system: the size of a disturbance that could be tolerated without fundamental change. The black line is an illustration of the possible current status.

Step 6

It is not possible to define where the threshold is, but even if it were possible, it is also impossible to predict how large the next fluctuation would be. Still, to get a good grasp of the situation, it is possible to describe the ideal value, the current value and a possibly catastrophic value for each slow variable. This exercise gives a rough estimation of the current situation.

Estimate roughly the state of your slow variables. Fill in Table 3:

Table 3. State of the slow variables. The ideal value is based on the best available science. The current value is measured if possible. The catastrophic value is a conservative estimate (the lowest that is still realistic) of a situation where a drastic change is inevitable. Max yearly change is understood in a worst-case scenario and hits at the maximum possible pace of change.

IDEAL VALUE	CURRENT VALUE	CATASTROPHIC VALUE	MAX. YEARLY CHANGE

DISTURBANCE REGIMES

In all agroecosystems, there are disturbances: storms, floods, pest outbreaks, droughts, economic shocks, diseases (human or non-human), and so on. Some disturbances are necessary to keep the system healthy — without these, biodiversity would decline and the conditions for production could not be renewed. Yet, disturbances cause economic challenges when they happen.

With climate change and other unfolding ecological changes, patterns of disturbances might change: they may be more frequent or more severe, and sometimes new recurring disturbances are to be expected. These new disturbances could become part of a new normal and new management is necessary to prepare for them.

A typical example is changing water management to prepare for the effects of climate change. Land usage, crop or landscape structure might need to be changed to smooth out the effects of fluctuations in water availability. Scientific analyses about the expected new patterns are often available, if not specific to the agroecosystem in question, then about the broader geographical area or similar systems elsewhere. Adaptation to a new normal cannot be solely financial support — these just conserve the not-resilient management structures that are not likely to be subsidized for a very long time.

Step 7

A disturbance regime is a stable pattern of recurring disturbance events (e.g. a small flood every 2 years, a major flood every 10 years, a devastating flood every 100 years.)

Describe your old and new disturbance regime. Fill in Table 4:

Table 4. Changing disturbance regimes. Disturbances can be both ecological and social, they are part of the system, cannot be eliminated, and always cause short term losses. Here, the two parts of the table compare the old pattern to a new normal.

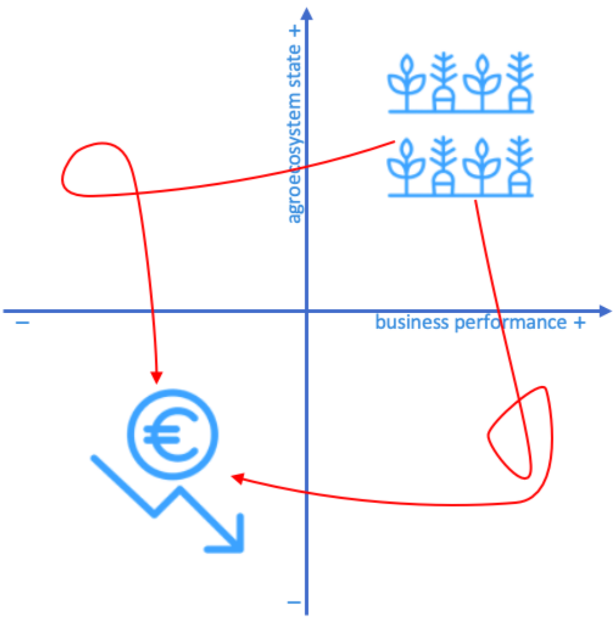
OLD DISTURBANCE REGIME		NEW DISTURBANCE REGIME	
DISTURBANCE	FREQUENCY	DISTURBANCE	FREQUENCY

TIPPING POINTS

Steps 6 and 7 were focusing on where we expect fundamental changes in the system. Unfortunately, though there is no possibility to define the distance of the tipping point, not even well-equipped scientific research could determine it precisely in a real-life system. This makes it particularly important to think about what kind of tipping elements could be in the system and, roughly, how far they are, so preventive measures can be taken before a dangerous situation is approached.

When a tipping point is reached, a cascade of changes is often initiated. The most obvious of these is the connection between the ecological state and the economic performance of the farms. If pollinators collapse, the water table drops, and soil salinity increases, then costs of keeping up production rise and this might drive the company towards bankruptcy. On the other hand, if the farm is in poor economic condition, it usually tries to squeeze out as much income from the land as possible — using chemicals, homogenizing the landscape and with cheap technologies. This process often leads to ecological deterioration; thus, financial trouble can also lead to ecological collapse. Having a high-quality ecological system and low economic performance is rare in agroecosystems — as the opposite is also barely possible: having long term profit on low-quality land (Figure 8).

This means, that business and conservation need to work together to ensure that both parties can maintain a necessary level of stability.



Such tipping points do not directly rely on slow variables but on ecosystem services. What are the most important ecosystem services for the local economy and society?

Figure 8. Cascading change. Only a high-quality ecosystem and high business performance or collapse on both sides are stable. Good business in a poor environment or great ecological state with financial stress will not be sustained for a very long time.

What level of their production is necessary to sustain or develop the system? If these ecosystem services and their necessary levels are identified, slow variables that ensure their resilience can also be found and their management can be adjusted if necessary. These services were identified in Step 3.

Thus, to sum up, slow variables determine the stability of ecosystem services. In the long run, ecosystem services provide income in agroecosystems and business activities influence the state of slow variables through various management decisions. These three have all to be taken into account to find a balance in the system (Figure 9).

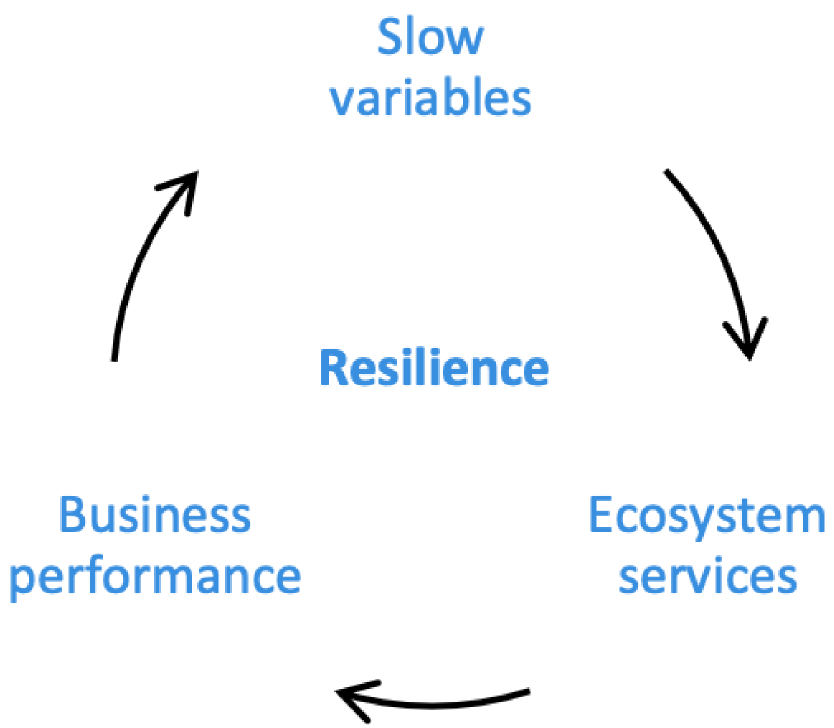


Figure 9. Summary of the interconnection between ecosystem services, business and slow variables.

BUILDING RESILIENCE

WHO IS INVOLVED IN MANAGEMENT?

In the management of key ecosystem elements (or slow variables) always multiple stakeholders are involved. Some make regulations, some monitor, some implement specific measures, others use the resources, and some others benefit from the results of these measures. There might also be stakeholders who are side-lined, excluded or who are losing money as a result of the current management.

Step 8

List slow variables and stakeholders in Table 5 and mark who is using or managing each of the slow variables. While there often are connections between the different slow variables, it is necessary to recognize which stakeholders have to cooperate in achieving desirable outcomes in the management of the different slow variables.

In the last row, the results of Step 6 should be compared to the expected future disturbances identified in Step 7 (right side of the table). If the state of the slow variable deteriorates, a small number of future shocks might cause serious damage to the entire system. In other cases, the system might have more resilience.

Table 5. Slow variables and stakeholders. An example of how various stakeholders might be involved in the management of different slow variables. In the last row, the state of each slow variable is assessed based on their distance from the threshold and the severity of the expected shocks.

	WATER TABLE	LANDSCAPE STRUCTURE	INVASIVE SPECIES
Small farms	X	X	X
National park		X	X
Hotels	X		
National gov.	X	X	
EU regulators		X	X
STATUS	critical	deteriorated	good

PATHWAYS

Having analysed the historical development and the most likely challenges of the system, a vision of a resilient and desired state can be described. What would be an ideal state that is prepared for climate change, economic fluctuations and other challenges?

Future scenarios should be described in terms of *states of slow variables and institutions of governance*. Slow variables are not enough to define a stable state as the right social institutions and management practices are necessary stabilizing elements for them. Scenarios need to describe the management structure, decision making and economic processes that constitute the social domain of the stable state.

Usually, there is one scenario that is most desired by workshop participants. How do we develop a realistic path toward that state?

Interventions can be categorized as coping, adaptation, or transformation. (1) Coping is not a systematic response; it is a short-term solution to maintain system function or mitigate damages. (2) Adaptation changes system behaviour to sustain functions in the presence of a persistent threat or damage, while the basic structure of the system remains the same. (3) Transformation integrates the threat as a new driver, changes system behaviour, and accepts the challenge as part of the new normal.

Lasting interventions need to step behind the level of coping and often must aspire to transformation. In the age of climate change, new and strong external drivers cannot be influenced at the local level.

Step 9

Answer the following questions:

- What is the desired level of the slow variables and what are their main stabilizing elements?
- What institutional arrangements would ensure that stabilizing elements remain in place?
- What would be the most efficient way of monitoring slow variables?
- What would be the smallest and cheapest possible step to move toward the desired scenario?
- Is there more than one such possible experimental intervention?
- What knowledge or data is missing? Is it possible to gather this data from stakeholders? Is it possible to connect data-gathering to experimental steps of implementation?
- What would be early proof that the new strategy works in practice?

UNKNOWNS

What are the unknown elements of the future or present? List all the unknown, uncertain factors that might influence the implementation of the desired pathway. There are multiple forms of uncertainty:

- Missing data due to no monitoring, or data is inaccessible (e.g. the water table level is not monitored)

- Future change is expected, but hard to forecast with acceptable accuracy (e.g. how rainfall patterns change due to climate change)
- Policy changes (e.g. changes in CAP payments are expected but unknown)
- Missing details in system data (e.g. no geospatial analysis of flood-risk zones in settlements while floods are expected in the near future)
- Unknown, unexpected consequences of planned interventions (e.g. planned introduction of large carnivores and their effect on tourism or animal farming)

Step 10

List all unknowns that might influence the implementation of any of the possible scenarios.

MONITORING AND EXPERIMENTS

Monitoring informs about the state of the system and about the outcome of changing interventions or experiments. In adaptive management, all interventions are treated as experiments, all rules as hypotheses, and monitoring is the tool to verify or falsify our assumptions.

Monitoring is a powerful tool to involve stakeholders and generate meaningful discussion. If stakeholders agree on some form of data collection and evaluate results together, they may also agree more easily about the necessary steps or possible experiments that would uncover the way forward.

If there is no agreement about the expected outcome of an intervention, or multiple interventions are proposed, the best solution is to conduct parallel experiments that enable the system to show all the outcomes.

Step 11

- Define possible interventions and make forecasts about how they would unfold.
- Plan experiments on the smallest meaningful scale and discuss the right way of monitoring and evaluating results.
- Set up a system of monitoring with the involvement of stakeholders: “Do it yourself” (DIY) measurement tools are often sufficient; transparent data and collaborative evaluation is necessary.

COST-BENEFIT ANALYSIS

If multiple scenarios are possible, stakeholders will most likely prefer different ones. Probably, the single most important reason for this is financial interest that is often driven by the agriculture subsidy system. Even if this is hard, it is necessary to tackle this issue. A simple cost-benefit analysis is a helpful starting point.

Step 12

For each scenario, consider (1) costs, (2) benefits, and (3) risks of all relevant stakeholders.

Table 6. Example cost-benefit analysis (excerpt from a real RA conducted by CEEweb). Red values are losses, green values are benefits, and blue values are risks.

	SCENARIO 1	SCENARIO 2
Stakeholder 1	decreasing yield, new subsidies available, potential need for irrigation	losing area under farming, increasing yield, flood risk increased
Stakeholder 2	property value remains, flood risk	property value declines, change of municipal zonation rules
Stakeholder 3	declining biodiversity, lake drying up	more invasive species, improved biodiversity, tourism with possible side-effects

ADAPTIVE MANAGEMENT IN ACTION

Adaptive management builds on the understanding that a social-ecological system is a complex, self-organizing entity that responds to all events. Therefore, no one-size-fits-all solutions or top-down goals can be implemented successfully.

When adaptive management is introduced, the following questions should be reflected upon:

1. **What is the overall goal of management?** How does this goal relate to the current stable state of the system? Are we fighting, suppressing ecological processes, or are we cooperating with them? Agriculture will never be fully in line with nature's self-regulation, but it is possible to do agriculture while not eroding the resilience of the system.

2. **If there is a problem, how does the manager know what action is best to take?** Is it possible to test the intervention as a hypothesis? What would be the indicator of success or failure in that test intervention?
3. **What might be a blind spot in the current management strategy?** Is there an emergent economic change, invasive species or new regulation that causes unknown consequences? Is there a way to test multiple possible responses before taking a strategic decision?
4. **What do different knowledge systems say about the current challenge?** Is there a scientific analysis about a similar case somewhere? Is there a knowledgeable local practitioner who could recall a practical experience that was never in the textbooks? Can we form a hypothesis about this new challenge and think about how we could test if the hypothesis is true?
5. **Who is affected by this question?** How do they see it? Is it a challenge or an opportunity for them? Do they agree with the analysis of the manager? What is their view? What data can they provide? Do they share goals? How can we act together?
6. **Is there a time for transformation?** Maybe the system is in deep trouble, or some future change seems to be inevitable. Examples of such change might be a transition to organic agriculture, radically changing crops or landscape patterns, accessing different markets after a large investment, etc. Sometimes, large-scale change is necessary. In such a case, the first five questions also apply, but are even more important — leadership, participation, shared vision, a good understanding of the processes, and openness to change strategies are all necessary to transform an agroecosystem.

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Resilience in agroecological systems is the capacity to adapt to pressures like droughts, floods, pest outbreaks, economic shocks, and more. Primarily as a consequence of climate change, these shocks will occur more often while industrial agricultural practices have changed landscapes across Europe to be less resilient. In every corner of the continent, it is just a matter of time when the impacts of the ecological crisis will surprise local farmers.

While curbing climate change by reducing greenhouse gas emissions is a task on a continental (and global) scale, adaptation is local, it needs to be specific to every landscape and every society.

This workbook helps stakeholders in agrarian landscapes to increase resilience and maintain mutually beneficial cooperation between humans and nature.

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